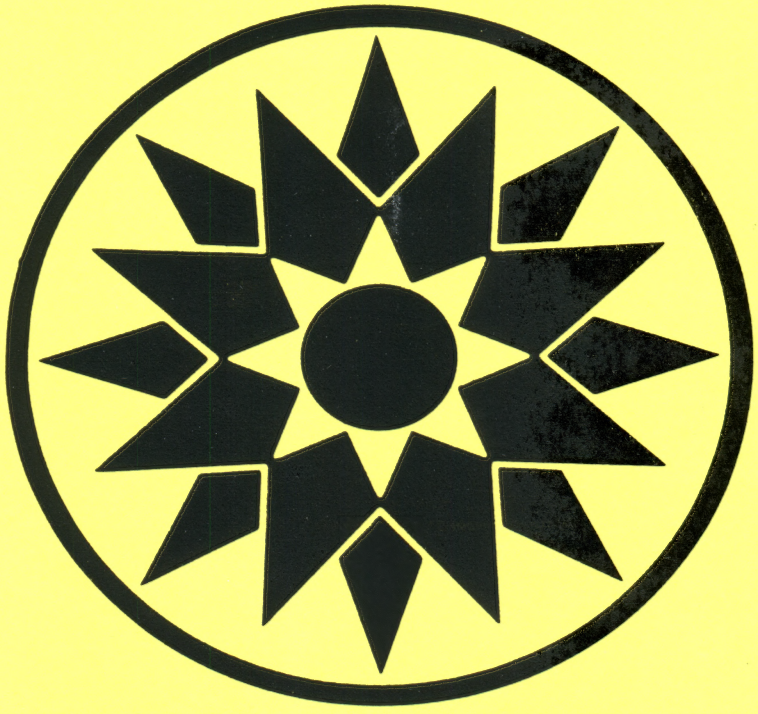
Teacher's Guide

Playing with Science: Temperature

Apple



SUNBURST
COMMUNICATIONS

PERMISSIONS

All SUNBURST material is copyrighted. However, SUNBURST does give the purchaser the following permissions:

1. You have permission to reproduce any student worksheets in this guide for your classroom use. You should not, however, copy the whole guide.

2. You have permission to use Lab Packs within one site. You should not, however, divide the package and use the disks in more than one building.

3. You may not copy this disk. A back-up is provided.

4. You have permission to allow students to take the product home for use with their personal computer.

Designer:	Leslie Eiser
Programmer:	Dominique Allard
Teacher's Guide:	Leslie Eiser
Technical Assistance:	Sean Huxley
Project Manager:	Charles F. Brock
Thanks to:	John W. Layman, Marvin L. DeJong, and James H. Nelson of the *AAPT Microcomputer Workshop on Laboratory Interfacing Experiments Using the Apple II Microcomputer Game Port*; Robert Tinker; Tom Ford.

Copyright 1988, 1989
Sunburst Communications, Inc.

Apple is a registered trademark of Apple Computer.

For information or a free microcomputer courseware catalog, write:

SUNBURST COMMUNICATIONS
39 WASHINGTON AVE.
PLEASANTVILLE, NY 10570

In the United States, call toll-free: (800) 431-1934
In Canada, call toll-free: (800) 247-6756
Or call collect: (914) 769-5030

PLAYING WITH SCIENCE: Temperature
TABLE OF CONTENTS

Introduction 1
Objectives 3
Installing the Hardware 4
Getting Started – A Simple Experiment 7
Calibrating the Thermistors 9
Program Description
- Program Overview 10
- Set Up an Experiment 13
- **Experiment** 20
- **Analyze Data** 27
  - Type 33
  - Zoom 34
  - Select Thermistors 38
  - Pick Points 39
  - See Data 42
- **Utilities** 43

Activities
- Overview 51
- Activities by Suggested Grade Level 54
- Activities by Standard Topic 55
- Group 1 **Playing with Hot and Cold!**
  - How does a thermometer work? (1-1) 56
  - Why does the liquid in a thermometer rise when the temperature rises? (1-2) 63
  - What do we mean by hot, cold, and lukewarm? (1-3) 66
  - What is the best source of heat? (1-4) 73
  - Can you guess what someone is doing by looking at a graph? (1-5) 77
- Group 2 **Learning about your body**
  - Can water be hot and cold at the same time? (2-1) 83
  - How does your skin detect temperature? (2-2) 91
  - Is the temperature of the air you breathe out warmer or colder than the air you breathe in? (2-3) 96
  - How are you different from your neighbor? (2-4) 104
- Group 3 **Why do things get warmer?**
  - Do different materials let the same amount of heat pass through? (3-1) 109
  - How far from a fire can you sit and still feel warm? (3-2) 117
  - What color clothing is the warmest? (3-3) 124
  - In and out, can heat go both ways? (3-4) 131
  - Why are gloves warm inside? (3-5) 137
  - What happens to air when it changes temperature? (3-6) 143
  - Is there a microclimate in your classroom? (3-7) 148

Group 4 **Learning about sunshine**
What happens when the sun shines? (4-1) 155
What makes rocks hot? (4-2) 158
Which gets hotter, black asphalt or grey pavement? (4-3) 162
Where is the warmest place to sit in the school yard? (4-4) 168
Why is it colder in the winter time? (4-5) 175
What is the weather in your classroom like? (4-6) 178
Can you build a solar cooker? (4-7) 182
Group 5 **Learning about water**
Why do we feel cold when the wind blows? (5-1) 185
Can we measure the cooling effect of evaporation? (5-2) 189
What happens when soda water freezes? (5-3) 194
Why does it take so long for large blocks of ice to melt? (5-4) 199
Can you boil water in a paper bag? (5-5) 207
Why is the bottom of the ocean so cold? (5-6) 214
What happens when we "salt the water?" (5-7) 218
Group 6 **Coffee cups and temperature**
What happens to a cup of coffee when it sits for several minutes? (6-1) 226
What is the best material to use for a coffee cup? (6-2) 233
How does the diameter of a coffee cup affect its ability to keep the coffee warm? (6-3) 240

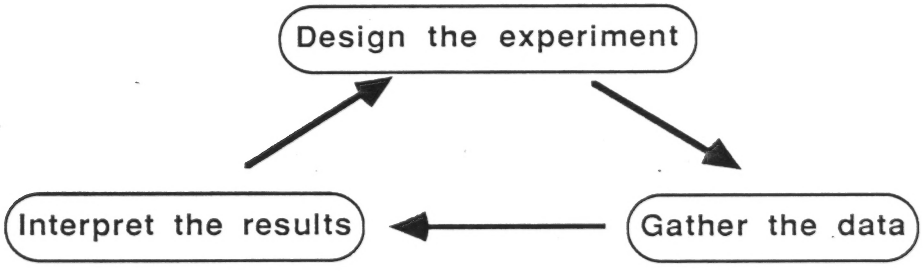
Miscellaneous
Hardware Technical Guide 246
Bibliography 257
Working with Your Computer: Apple II+, IIe, IIc 258
Working with Your Computer: Apple IIGS 259
What Happens If..? – Sunburst Courseware and Warranty 260

PLAYING WITH SCIENCE: Temperature
INTRODUCTION

How can we keep warmer in winter? Why are black cars so hot inside in the summer time? What happens when water freezes? Why are gloves warm? Is the air you breathe in warmer or cooler than the air you breathe out?

Questions like these demand real answers, not simple verbal explanations. These answers can only be found by systematically exploring the world around us – by "Doing Real Science". Giving school children the opportunity to "do science" requires that the teacher share with the students a willingness to take chances and risk making mistakes by asking questions, gathering data, and brainstorming for answers in a logical manner. The nicest thing about teaching elementary science in this way is that it doesn't require a specialized background. With the right materials and a desire to explore, anyone can start **PLAYING WITH SCIENCE**.

Real science questions can be approached by following the three fundamental steps of experimentation: Design the Experiment, Gather the Data, Interpret the Results. Once the results have been interpreted, the experimental design can be modified and the steps repeated until a reasonable answer is found. Encouraging students to work through this circle is often a difficult job, and much of the science material available at the elementary level uses a single question/single answer approach. The material that accompanies **PLAYING WITH SCIENCE: Temperature**, however, provides students with the opportunity to play a more fundamental role in their own learning process. By presenting real questions and then using the power of the computer to aid in data collection, emphasis is placed on letting the students discover their own answers, rather than on the physical skill of reading a thermometer and recording the results.



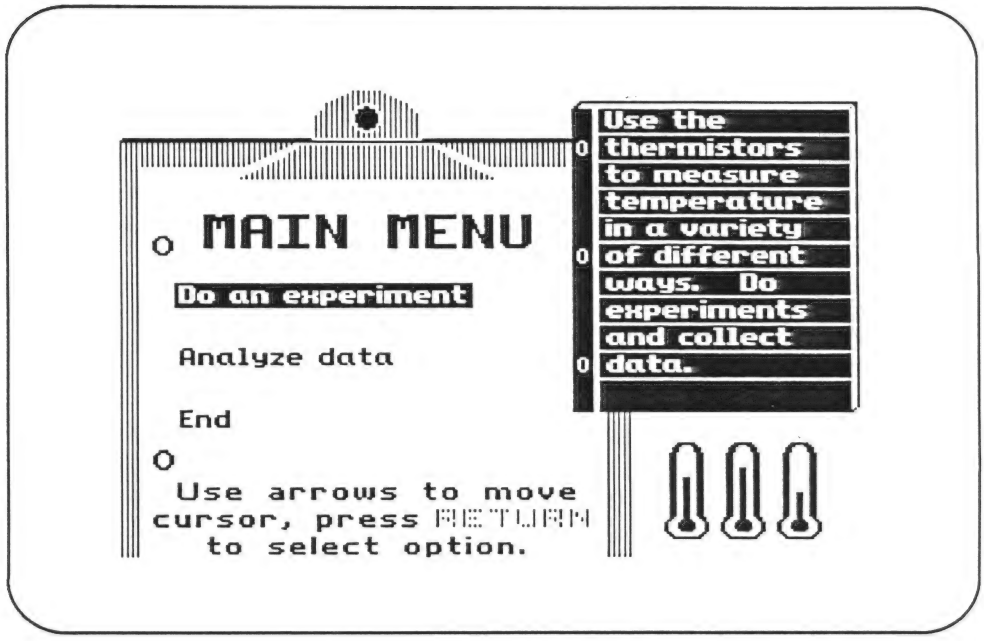
PLAYING WITH SCIENCE: Temperature provides two unique tools. In EXPERIMENT, data is recorded with up to three different thermistor probes and is simultaneously presented in any of four easy-to-follow displays. Instead of forcing students to spend their time trying to record the data, the computer frees them to see what is happening *while the experiment is being performed!*

In ANALYZE DATA, the computer provides an interface between the large amounts of data collected and the student scientist. Graphs can be quickly drawn, scales changed, sections enlarged and enlarged again for close inspection. The computer provides flexibility and convenience while the student tries to explain the results.

PLAYING WITH SCIENCE: Temperature is tool software – it provides students with a sophisticated and powerful resource to explore the world around them. The classroom lessons, all of which are designed to be done within a 45 minute class period, provide the structure for learning and make it easy to bring this tool into your classroom.

PLAYING WITH SCIENCE: Temperature is designed to operate on an Apple IIe, IIc, or IIGS, or on an Apple II+ (with 64K and an adapter cable). Instructions on how to install the required hardware can be found in the section entitled Installing the Hardware. If you need assistance in operating your computer, check the section entitled Working with Your Computer or call Sunburst toll-free at 800-431-1934 (U.S.), 800-247-6756 (Canada).

PLAYING WITH SCIENCE: Temperature
OBJECTIVES


MAIN MENU
Do an experiment
Analyze data
End
Use arrows to move cursor, press RETURN to select option.
Use the thermistors to measure temperature in a variety of different ways. Do experiments and collect data.

OBJECTIVES:

To provide students with a powerful tool to measure temperature.

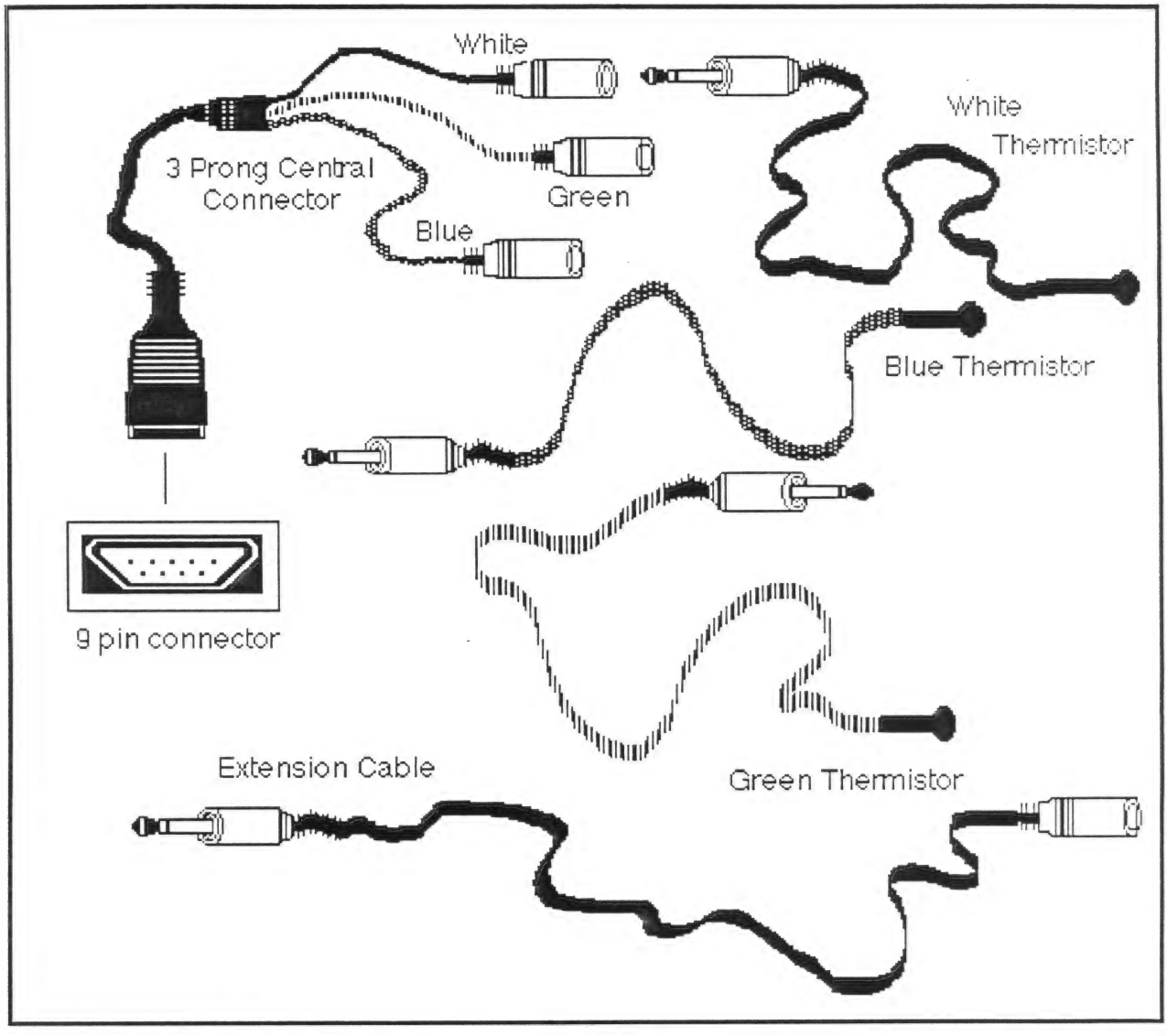
To provide an environment that makes sophisticated experiments easy enough for elementary students to perform.

To teach students how to apply the three fundamental steps of experimental design: Design the Experiment, Gather the Data, and Analyze the Data.

GRADE LEVEL:

Software and Hardware: K – adult
Classroom Lesson Plans: K – 7

PLAYING WITH SCIENCE: Temperature
INSTALLING THE HARDWARE



Description

The **PLAYING WITH SCIENCE: Temperature** hardware consists of five pieces:

1	3 Prong Central Connector
3	Color-coded Thermistor Probes (White, Blue and Green)
1	Extension Cable

Step One: First install the 3 prong central connector by connecting it to your Apple II game port:

Apple IIe/IIc/IIGS

If you have an Apple IIe, IIc, or IIGS, simply plug the 9-pin connector into the external game port. This port is found on the back of the computer. Reach behind the computer on the right and you will feel it with your fingers. There is only one right way to do this, so if it doesn't fit easily, turn the connector upside down and try again.

This completes Step One.

Apple II+

If you have an Apple II+, you will need an Apple II+ adaptor cable available separately from Sunburst.

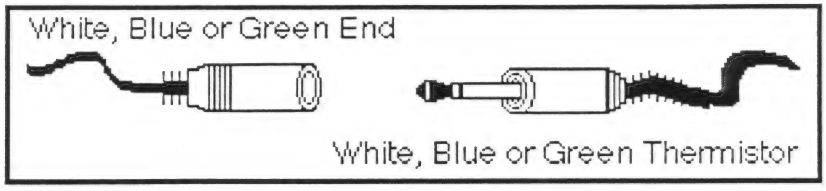
- First turn off the computer, but leave the power cable connected. Open up the computer, and look inside. In the upper right corner of the main board (called the motherboard) is an empty 16 pin socket. It is tucked under the lip of the frame of the computer itself and may be a little hard to see. To prevent static discharge, be sure to touch the power supply *before* you touch anything inside the computer.

- You must plug the male 16 pin connector of the Apple II+ adaptor cable into this socket. Thread the cable through one of the holes in the back of the computer first, with the cable from the connector extending towards the back of the computer. Carefully center the 16 pins above the empty socket, and when every pin lines up with a hole, push the two together. They should fit together easily. When you have completed this installation, close the cover firmly.

- Now plug the 9-pin female end of the Apple II+ adaptor into the 9-pin male end of the 3 prong central connector.

This completes Step One.

Step Two: Insert the appropriate thermistors into the ends of the 3 prong central connector.



Remember to match the colors as you go. Only the white thermistor must be connected at all times. The others may be connected as needed. The extension cable can be added at any time by unplugging the thermistor, plugging the extension cable into the 3 prong central connector, and plugging the thermistor into the other end of the extension cable again.

This completes Step Two.

Note: If you are using an Apple IIc, only the white and blue thermistors will work. You must use an Apple II+, IIe, or IIGS if you want to do experiments that require the use of all three thermistors.

Step Three: Set-up your printer and make at least one data disk.

- Boot the **PLAYING WITH SCIENCE: Temperature** program. When the Main Menu appears, hold down the CONTROL key and press the T key to access the UTILITIES.
- Use the arrow keys to highlight *Printer Selection* and press RETURN. After a brief pause while printer options are loaded in, you will be asked to identify the type of printer and interface card you are using. Follow the prompts that appear or consult page 49 in this guide for more detailed instructions. When you have finished, answer *N* to the prompt to return to the UTILITIES menu.
- Now use the arrow keys to highlight *Disk Commands* and press RETURN. Select *Format a data disk* and press RETURN again. Follow the prompts on the notepad to make at least one data disk.
- Press ESC twice or use the exit selections to leave the UTILITIES and return to the Main Menu.

This completes Step Three.

You are now ready to begin using
PLAYING WITH SCIENCE: Temperature

PLAYING WITH SCIENCE: Temperature
GETTING STARTED: A Simple Experiment

The following instructions show you how to start using **PLAYING WITH SCIENCE: Temperature** right away in a simple experiment. By switching the thermistor probes from hot to cold water and back again, you can see how data is collected and then how the data reflects the events of the experiment.

1. First install the hardware by following the directions on pages 4-6. Make sure that the white and the blue thermistors are connected. If you want to save data after Step 10, you must first format a data disk using the *Format a data disk* option in the UTILITIES. Similarly, if you wish to get a printed copy of your results, you must first use the *Printer Selection* option in the UTILITIES. See pages 44 and 49 for more details.

2. Place the **PLAYING WITH SCIENCE: Temperature** disk in Drive 1 and turn on the computer. While the program is loading, get cups of hot water and cold water.

3. The Main Menu will appear. Select DO AN EXPERIMENT by using the arrow keys to move the highlighter and pressing RETURN. Options on all menus may be selected in this manner.

4. The Set-Up Menu will appear. Select *Time* with the arrow keys and press RETURN. Set the time limit to 5 minutes by highlighting *minutes* and typing 5. Press RETURN once to accept this information and once more to leave this menu.

5. Select the EXPERIMENT option by moving the highlighter and pressing RETURN. The EXPERIMENT screen will appear. Notice that START is already highlighted. Begin taking data by pressing RETURN once. Both the blue and white thermistors should now be reading room temperature, anywhere from 18°C to 30°C (65°F to 85°F). If they are not doing so, check all of your cable connections and try again. If they still do not work, please call Sunburst Customer Service.

6. Hold the very tip of the white thermistor in your hand. Watch what happens to the temperature. Now place the white thermistor in a cup of cold water. What happens to the display graph?

7. Place the blue thermistor in a cup of hot water. What happens to the display graph now?

8. Count to ten, and then switch the thermistors. The white thermistor is now in the hot water and the blue thermistor in the cold water. What happens to the graph? When the temperatures stop changing rapidly, press RETURN to stop taking data. How long did it take you to switch the thermistors? How can you tell? Could you do it faster?

9. Press RETURN to start taking data again. Try the switching procedure once more. Did you beat your old time? How do you know if you were faster or slower than before?

10. Switch the thermistors several more times. Do it very slowly, and then very quickly. After you have switched them at least 5 times, press RETURN to stop taking data. If you have a data disk already prepared, you may choose *Disk Options* to save your data before continuing with step 11.

11. We can now take a closer look at our data by using ANALYZE DATA. Select *Graph* from the Menu Bar by highlighting it and pressing RETURN, and then select the *Analyze* option. Select *Yes* when asked if you are sure, and press RETURN. After a short pause, the ANALYZE DATA screen will appear.

12. Now you can see all of your data at once. Can you pick out the times when you switched the thermistors? Which was the fastest? Which was the slowest?

13. To make the graph easier to read, let's zoom in on a small section. Select *Graph*, and then *Zoom*. We will use the *Zoom* submenu to choose a small piece of the data and then let the program enlarge it for us.

14. Choose *Set Corner* and use the arrow keys or the I, J, K, and M keys to move the cursor around the box in the lower right corner. This is a graphical representation of the entire set of data. Pick a position to the left and below the beginning of one of the switches, and press RETURN.

15. Notice that the cursor has now jumped to *Set Size*. Use the arrow keys or the I,J,K, and M keys to change the size of the box around the data. When a section of the graph that shows the effects of at least two thermistor switches is enclosed in the box, press RETURN.

16. Now you can look at this portion of your data more closely. What does a switch look like on the graph? Can you pick out the beginning of a switch? The end? How could you find out how long a switch took to occur?

17. Is the temperature of the hot water changing over time? How can you tell?

18. Use the *See Data* option to see the actual values of the data points. Is it easier to tell which switch was faster? Was your intuitive guess correct?

19. Try selecting some of the other options on the *Graph* menu. *Type* will let you switch from a Line graph display to a Bar graph display. *Select Thermistor* lets you see the graph of only one thermistor at a time.

20. When you have finished, return to the Main Menu by selecting *Other* from the Menu Bar and then selecting *Main Menu*. Finish using the program by selecting END on the Main Menu.

This completes your first experiment with **PLAYING WITH SCIENCE: Temperature**.

PLAYING WITH SCIENCE: Temperature
CALIBRATING THE THERMISTORS

When you received your copy of **PLAYING WITH SCIENCE: Temperature**, a simple calibration had already been done. If you've tried **GETTING STARTED: A Simple Experiment** and are satisfied with the results, stop now. There is no need to recalibrate the thermistors. If you are not satisfied with the accuracy of your temperature readings but are sure that the thermistors are working properly, re-calibrate the thermistors by following these directions.

1. Boot the **PLAYING WITH SCIENCE: Temperature** program. When the Main Menu appears, hold down the CONTROL key and press the T key to access the UTILITIES.

2. Select *Calibration Utility* with the arrow keys and press RETURN. Follow the prompts that appear on the notepad.

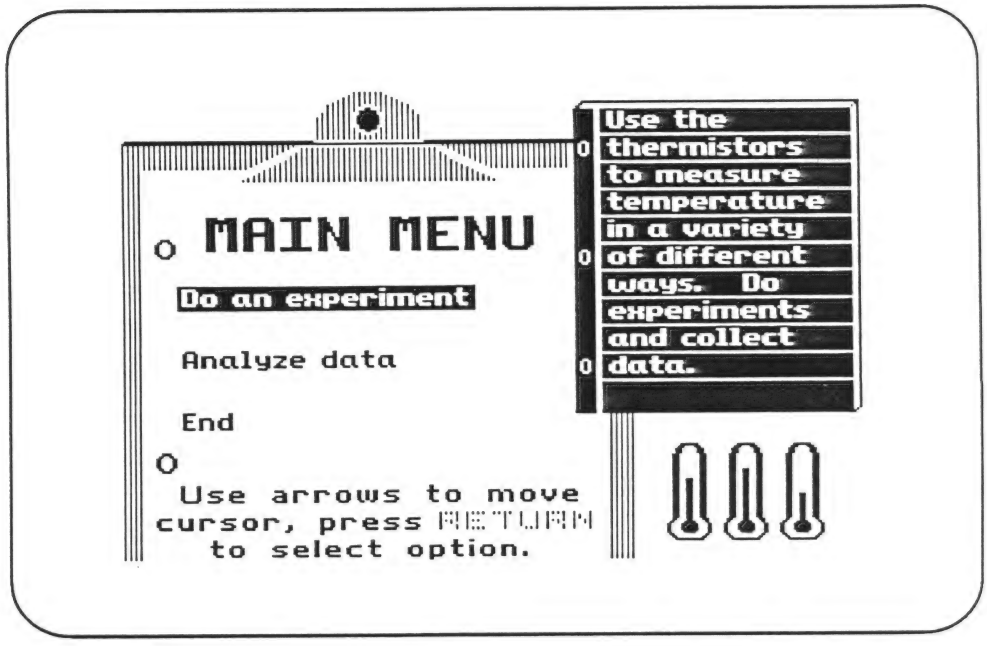
3. You will need a bowl filled with hot water (about 80°C or 175°F), a bowl filled with ice water (about 4°C or 40°F), and a standard thermometer. If this equipment is available, respond *Y* to the prompt and continue. If not, respond *N* to the prompt.

4. Follow the directions on the notepad carefully to insure that the calibration is done correctly. It takes about 3 minutes for the thermistors to become really stable in each temperature bath, so be prepared to wait until the program tells you to continue.

5. After successfully completing the calibration, you will be prompted to save the calibration on the **PLAYING WITH SCIENCE: Temperature** disk. If you are satisfied that it has been done correctly, select *Yes* and press RETURN.

6. Press ESC twice or use the exit selections to leave the UTILITIES and return to the Main Menu.

PLAYING WITH SCIENCE: Temperature
PROGRAM OVERVIEW


MAIN MENU
Do an experiment
Analyze data
End
Use arrows to move cursor, press RETURN to select option.
Use the thermistors to measure temperature in a variety of different ways. Do experiments and collect data.

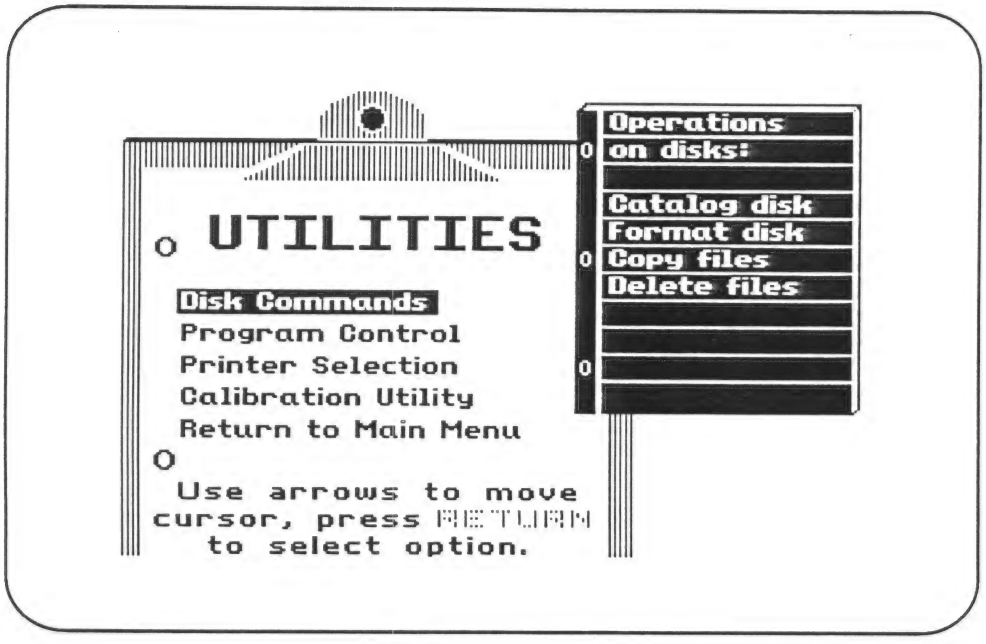
The Main Menu offers three options, plus the hidden UTILITIES.

Do an experiment – Permits the collecting of experimental data. The Set-Up Menu enables students to determine, before data is collected, the appropriate temperature range, the type of display desired, the length of time required for the experiment, and the number of thermistors to be used. The Set-Up Menu defaults may be preset and the menu suppressed so that students begin collecting data directly.

Analyze data – Permits close examination of data that has been collected. Data may be enlarged and displayed in different formats. By learning to control the analysis tools, students can display their data in virtually any desired format, freeing their time for more extensive analysis and evaluation of results.

End – Exits the program.

UTILITIES



The UTILITIES can be accessed by pressing CONTROL-T while the Main Menu is visible. UTILITIES include:

Disk Commands – Options to make and catalog data disks, and copy and delete files.

Program Control – Set program defaults. Specify either Celsius (°C) or Fahrenheit (°F), preset the Set-Up Menu, and hide the Set-Up Menu.

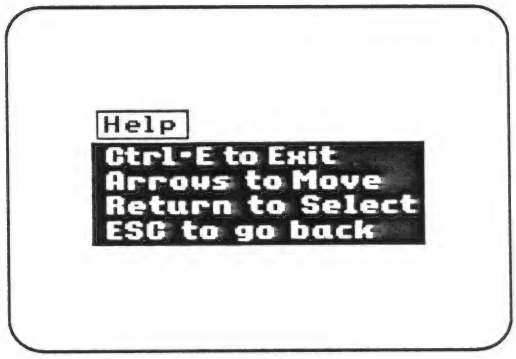
Printer Selection – Select your printer and interface card. Enables you to print out your data.

Calibration Utility – Calibrate each thermistor for accuracy, in °C or °F.

Return to Main Menu – Finish using UTILITIES and go back to the Main Menu.

See pages 43-50 for more complete descriptions of the UTILITIES options.

USING THE PROGRAM



Using **PLAYING WITH SCIENCE: Temperature** is very easy. A Help option is available at all times, listing the keys required in that section. The following descriptions add additional details.

MOVING BETWEEN OPTIONS: The arrow keys will move the highlighted cursor from option to option. Use the ← or ↑ keys to exit the submenus in the EXPERIMENT and ANALYZE DATA menus.

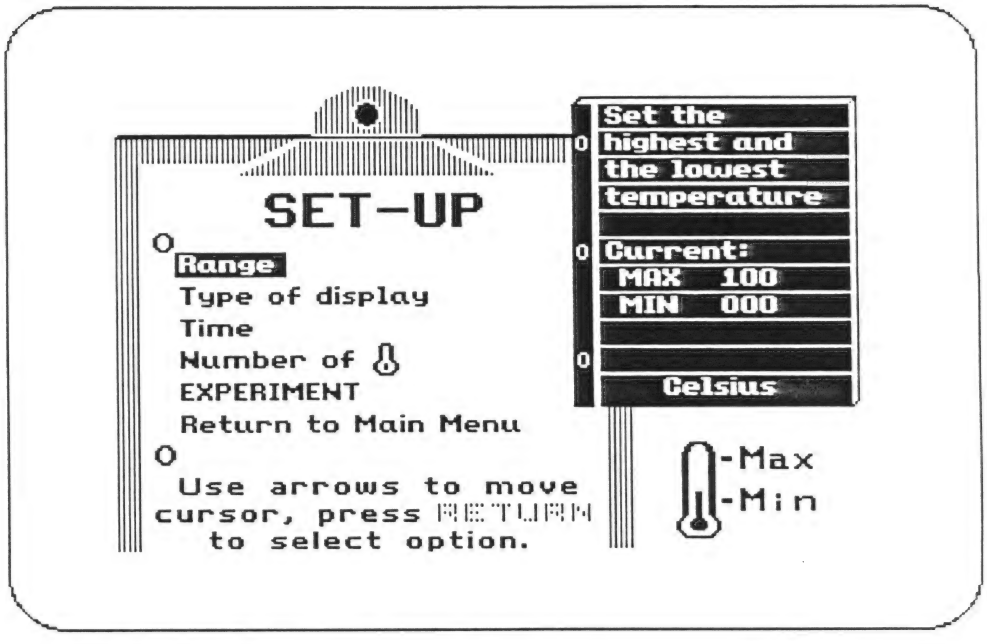
SELECTING OPTIONS: Use the arrow keys to move the highlighted cursor until the desired option is lit. Then press RETURN.

CHANGING VALUES: The numerical values of any of the parameters can be changed by highlighting the desired option and then typing in the new value. The arrow keys can also be used to change values after the option has been selected. The → or ↑ keys increase the values by 1, the ← or ↓ keys decrease the values by 1. Regardless of which method is used to change the value, RETURN must be pressed for that change to be accepted.

MOVING BETWEEN MENUS:

- To move to any menu or submenu, select the appropriate option and press RETURN.
- To cancel any submenu, press ESC.
- To move from EXPERIMENT to ANALYZE DATA, select the *Analyze* option under the *Graph* submenu.
- To move from EXPERIMENT or ANALYZE DATA to the Main Menu, press CONTROL-E.
- To move from ANALYZE DATA to EXPERIMENT or to the Main Menu, select the appropriate destination under the *Other* submenu.

PLAYING WITH SCIENCE: Temperature
SET UP AN EXPERIMENT



This portion of **PLAYING WITH SCIENCE: Temperature** corresponds to the Design the Experiment phase discussed in the Introduction. Before starting to collect data, students can set the values of all of the important parameters:

Range – Specify the temperature range that will be displayed while collecting data. The range is determined by setting both the maximum and minimum temperatures to be displayed.

Type of display – Specify in what format the data will be displayed. Line, Thermometer, and Digital displays collect data continuously, while Bar displays permit the collection of data in individual trials.

Time – Specify how long data is to be collected.

Number of thermistors – Specify how many thermistors to use in the experiment.

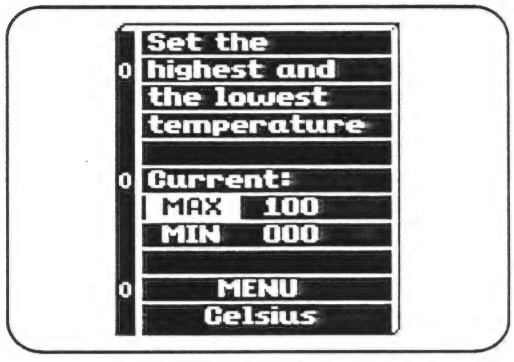
EXPERIMENT – Finish setting up the experiment and go to the experiment display.

Return to Main Menu – Stop setting up an experiment and go back to the Main Menu.

While it is good experimental design to estimate the parameters before doing the experiment (particularly *Range* and *Time*), one of the features of **PLAYING WITH SCIENCE: Temperature** is that it permits modification of the *Range* parameters *after* the data has been collected.

In the UTILITIES, there is an option to preset the default values of the parameters and to suppress the Set-Up Menu completely, thereby giving the teacher complete control over the set-up of the experiment.

Range



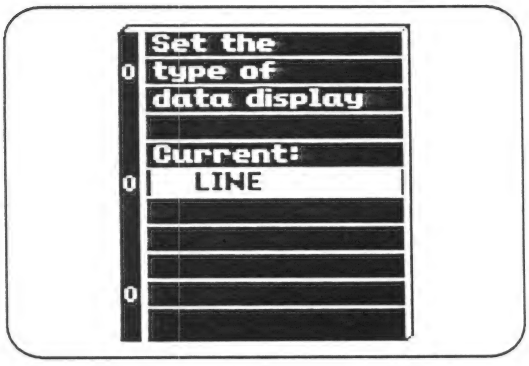
Default values: MAX: 100°C (212°F)
MIN: 0°C (32°F)

- Set the maximum and minimum temperatures to be displayed by highlighting *Range* and pressing RETURN. The MAX option will appear highlighted.
- Move the highlighter through the three options (MAX, MIN, and MENU) by pressing the arrow keys.
- To change MAX or MIN, highlight the option, and then type the desired value. Press RETURN to accept the information.
- You can also change MAX or MIN with the arrow keys by highlighting the option and pressing RETURN. Now the arrow keys will change the current value 1° at a time. Press RETURN to accept the information when you are finished.
- MAX must always be greater than MIN. If you wish to set a new range where the new MAX will be less than the old MIN, set the MIN value first.
- When you have finished setting the maximum and minimum temperatures, select the MENU option and press RETURN to return to the Set-Up Menu.

The accuracy of a thermometer is greatly dependent on its range. A standard school thermometer probably shows a minimum of -20°C or 0°F and a maximum of 120°C or 230°F. The range of this thermometer would be 120°C or 230°F, and it probably has an accuracy of 1°C or 2°F. In **PLAYING WITH SCIENCE: Temperature** the *Range* option is used to customize the maximum and minimum temperatures that are displayed while collecting data. Since MAX and MIN can be any value between the available extremes, the size of the range can vary from 1°C to 140°C. At a range of 1°C, the accuracy is better than 0.2°C.

For example, if you are studying the freezing temperature of water, the MIN can be set at -10°C and the MAX can be set at +10°C, for a total range of 20°C. If you are studying the temperature change during respiration, you can get the same accuracy (a range of 20°C) by setting the MAX and MIN to 15°C and 35°C respectively.

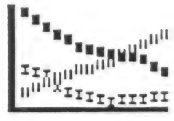
Type of display



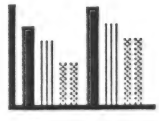
Default value: Line

- Select the style of display which will appear on the screen while the data is being collected by highlighting *Type of display* and pressing RETURN. The current setting will appear highlighted.
- Change the type of experiment display by pressing the → and ← keys.
- Press RETURN when the desired type of display is highlighted. The highlighting will return to the Set-Up Menu.

Line – Up to three independent line graphs are displayed simultaneously. By adjusting the maximum and minimum temperatures, even while the experiment is in progress, small changes in temperature can be observed while they happen.

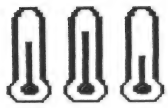


Bar – Data is collected in individual trials in the Bar display. 1, 2, or 3 color-coded bars appear per trial. Trials are sequentially numbered along the horizontal axis to make record keeping easier.



Bar graphs are useful for measurements that are not time dependent, like plant growth, hand temperature, or the temperature of a series of objects.

Thermometer – One to three large thermometers are shown on the screen. Simulated mercury moves in response to changes in temperature.

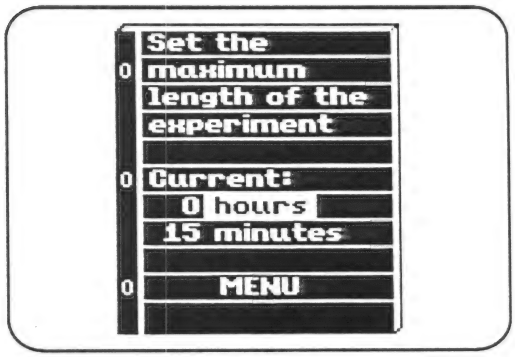


This display mode is excellent for use with young students who are not yet confident with standard data displays.

Digital – One to three large display boxes appear, in which the thermistor readings are displayed numerically.

This display mode is appropriate for a one computer classroom, since numbers are clearly visible across a classroom.

Time

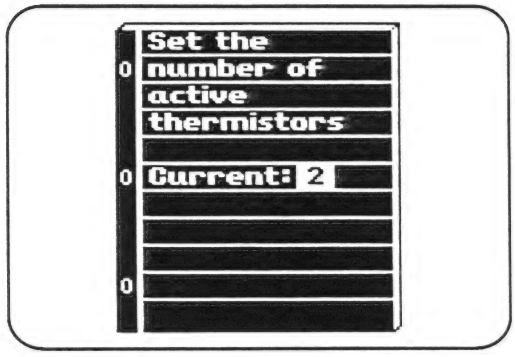


Default value: 15 minutes

- Change the length of the experiment by highlighting *Time* and pressing RETURN. The highlighter will appear on *hours*.
- Enter the number of hours for the experiment and press RETURN. The highlighter will move down to *minutes*.
- Enter the number of minutes for the experiment and press RETURN. The highlighter will move down to the MENU option.
- Press RETURN once more to return to the Set-Up Menu. Use the ↑ key to go back to change the length of the experiment again.

While **PLAYING WITH SCIENCE: Temperature** can record information from 1 minute to 23 hours 59 minutes, it is best not to use times longer than several minutes unless required by the design of the experiment. Since the frequency that the program can read the thermistors (the number of times the temperature is observed per second) is dependent on the length of the experiment, long experiments must take measurements much less frequently than short experiments. In general, times of 1 to 5 minutes are most effective. For most applications, the maximum time will be about 30 minutes.

Number of thermistors



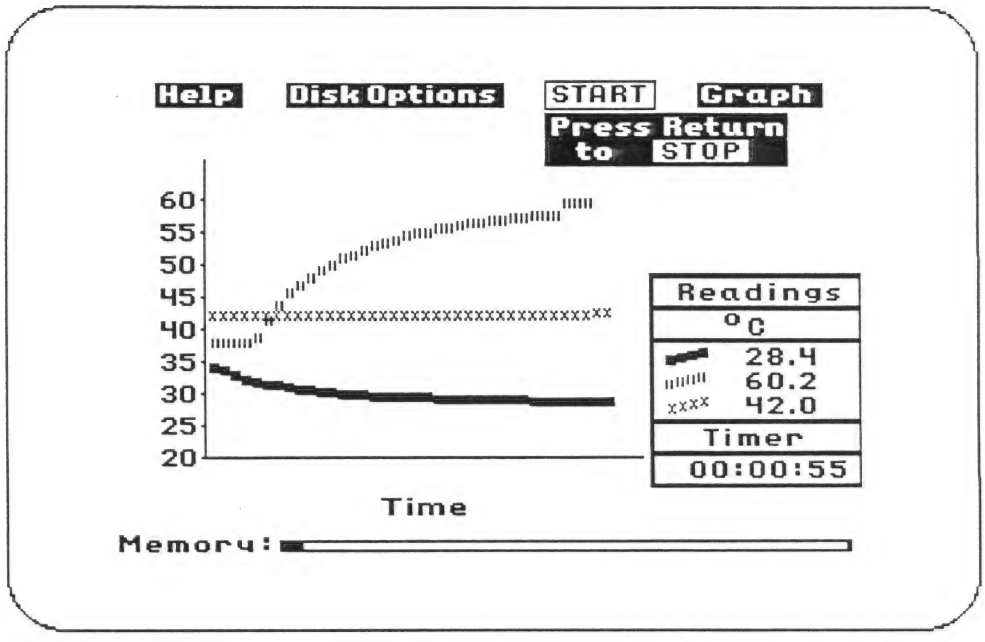
Default value: 2

- Specify the number of thermistors to be used by highlighting *Time* and pressing RETURN. The current number will appear highlighted.
- Change the number of thermistors by pressing the → and ← keys.
- Press RETURN when the desired number of thermistors is highlighted. The highlighting will return to the Set-Up Menu.

PLAYING WITH SCIENCE: Temperature treats each thermistor as a separate temperature source. To make the thermistors easier to use, they are color coded. The white thermistor is number one, plugs into the white jack, and must always be in place. The blue thermistor is number two, plugs into the blue jack, and must be in place if two are required. The green thermistor is number three and plugs into the green jack. If you forget to plug in the correct number of thermistors and try to do an experiment, the program will stop. A message will appear to remind you to check the thermistors before the computer can continue taking measurements.

Note: With an Apple II+, IIe or IIGS, **PLAYING WITH SCIENCE: Temperature** can use three thermistors at the same time. With an Apple IIc, only the first two thermistors (the white and the blue) can be used.

PLAYING WITH SCIENCE: Temperature EXPERIMENT



The EXPERIMENT portion of **PLAYING WITH SCIENCE: Temperature** is where the data is gathered and immediately displayed. EXPERIMENT corresponds to the Gather the Data phase discussed in the Introduction. Normally, this section is reached by selecting EXPERIMENT on the Set-Up Menu. If the UTILITIES have been used to suppress the Set-Up Menu, then EXPERIMENT is arrived at by choosing DO AN EXPERIMENT directly from the Main Menu.

Across the top of the EXPERIMENT screen is the Menu Bar with four options:

Help – Displays a brief list of useful keys and their functions.

Disk Options – Contains disk related options, including *Save* and *Link/Load*.

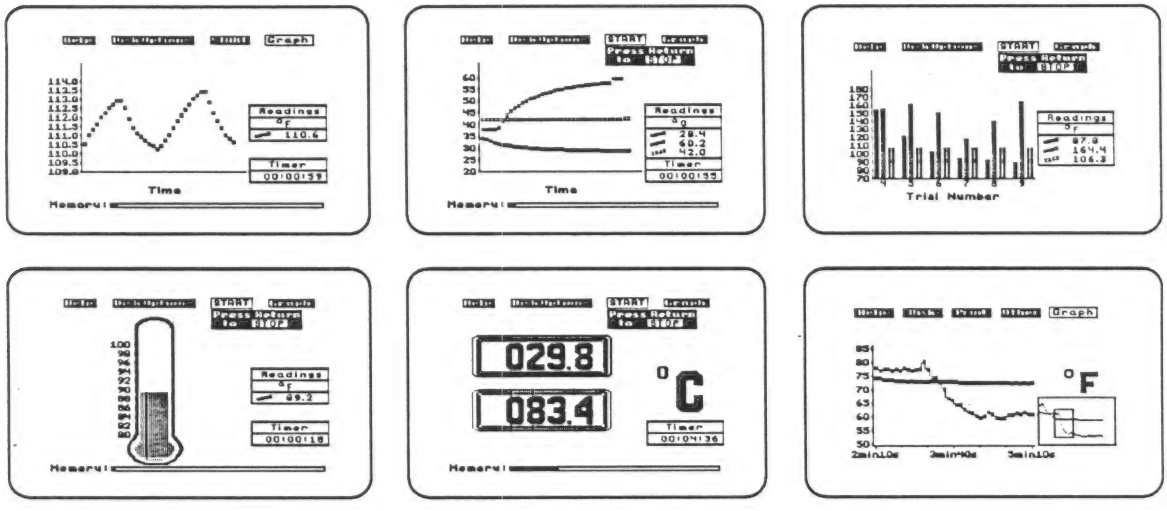
START – Causes the program to begin gathering data. Pressing RETURN again stops collecting data.

Graph – Contains options for changing the temperature range, for starting over, and for going to ANALYZE DATA.

At the bottom of the EXPERIMENT screen is a memory indicator that gradually fills in as data is collected. When it is full, **PLAYING WITH SCIENCE: Temperature** stops collecting data and displays a message. In order to continue, the data should be saved by selecting *Disk Options* and then *Save*. Memory should then be cleared by selecting *Graph* from the Menu Bar and then selecting *Start Over*.

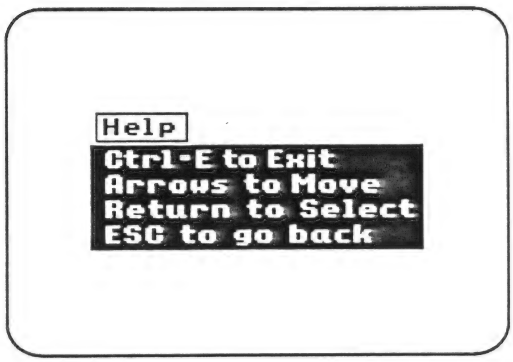
On the right of the EXPERIMENT screen is a display of the actual value of the thermistors as they are monitored. From one to three temperature readings will be displayed here, depending on the number of active thermistors. These measurements are shown to the nearest 0.1°. At the top of this display is the Celsius or Fahrenheit indicator. A digital clock is found near the bottom right if the display is time dependent (Line, Digital, and Thermometer displays). In the center of the screen is the actual data display. This section of the screen will fill and then scroll to the left as data is collected.

The actual appearance of the data display area depends on the values of the parameters determined on the Set-Up Menu:



- Select a menu option by first highlighting it with the arrow keys and then pressing RETURN.
- ESC, the ← key, or the ↑ key can be used to exit from a submenu.
- Go to ANALYZE DATA by selecting *Graph* on the Menu Bar and then selecting *Analyze*.
- CONTROL-E is used to leave EXPERIMENT and return to the Main Menu.
- For more details on specific keys and their functions, refer to the section on Using the Program, page 12.

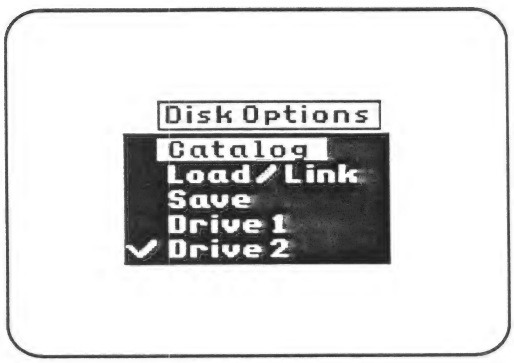
Help



The *Help* option displays a list of useful keys and their functions.

- Select the *Help* option with the arrow keys. Press RETURN to display *Help*.
- You can also display *Help* by pressing the ? key.
- Pressing RETURN, ESC, or any arrow key will cause the *Help* option to disappear.

Disk Options



The following options are available under *Disk Options*:

Catalog – See the files on your data disk before saving or loading a file.

- If more files are on the data disk than can be shown, press the ↓ key to scroll through the entire list.
- Press RETURN or ESC to stop viewing the catalog.

Load/Link – Permits adding new data to previously saved data.

- Use the arrow keys to choose a data file to be linked from the list of files and press RETURN.
- You will see the end of the old file appear in the data display area.
- Use the START command to add new data to the older set.

Save – Saves a copy of your experimental data on a data disk. Always use this option to save your data before leaving EXPERIMENT.

- Enter a name for your data file at the prompt.
- Check that there is a formatted data disk in the selected disk drive.
- Press RETURN to save your data.

Drive 1/Drive 2 – Choose the drive your data disk is in.

- Change the disk drive by highlighting the desired drive and pressing RETURN.
- A √ appears to indicate the selected disk drive.

START

The START option causes **PLAYING WITH SCIENCE: Temperature** to begin collecting data. Depending on the type of display, data will be collected continuously (the time dependent displays Line, Thermometer, and Digital) or discreetly (the trial dependent Bar display).

- Start collecting data by highlighting the START option with the arrow keys and pressing RETURN.
- Stop collecting data by pressing RETURN again.
- More data may be collected by highlighting the START option again and pressing RETURN.
- Begin a new experiment by selecting *Graph* from the Menu Bar and then select the *Start Over* option. Starting over clears all previously collected data from the computer's memory.

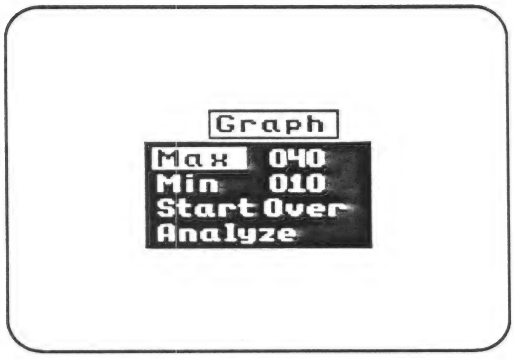
In the Line display mode, data is continuously collected and displayed in a scrolling line graph. The number of lines shown is determined by the number of thermistors being used.

In the Bar display mode, data is collected and displayed in a scrolling bar graph. One bar appears for each thermistor being used. Data is actually recorded only when RETURN is pressed again to stop the data collection. To collect another piece of data, reposition the thermistor(s) as desired and select START again. You can collect up to 40 pieces of data.

In the Thermometer display mode, data is continuously collected and graphically displayed by simulated thermometers. The number of thermometers is determined by the number of thermistors being used.

In the Digital display mode, data is continuously collected and digitally displayed in large boxes. The number of display boxes is determined by the number of thermistors being used.

Graph



The following options are available under *Graph* :

MAX – Changes the maximum temperature displayed in the Line, Bar, and Thermometer displays.

- Change the maximum temperature by highlighting MAX and typing the desired value.
- Alternatively, you can change the maximum temperature by pressing RETURN to select MAX and then using the arrow keys to adjust the temperature 1° at a time.
- Press RETURN to accept the new maximum temperature.

MIN – Changes the minimum temperature displayed in the Line, Bar, and Thermometer displays.

- Change the minimum temperature by highlighting MIN and typing the desired value.
- Alternatively, you can change the minimum temperature by pressing RETURN to select MIN and then using the arrow keys to adjust the temperature 1° at a time.
- Press RETURN to accept the new minimum temperature.

Start Over – Clears all previously collected data from the computer's memory.

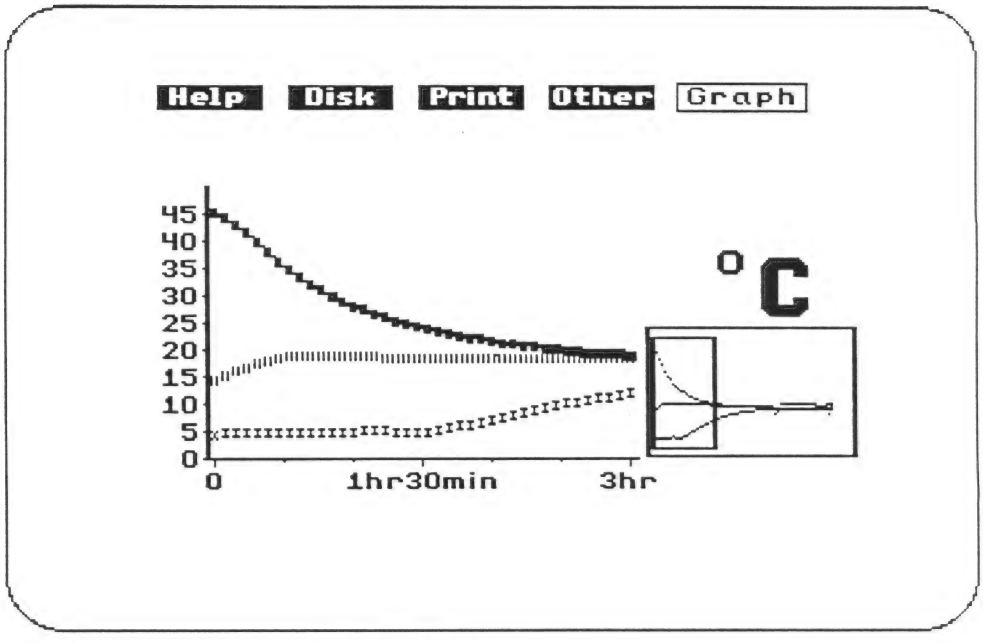
- Select *Start Over* and press RETURN. Another window will appear asking *Are You Sure?*
- If you answer *Yes* by using the ← key and pressing RETURN, all data in memory will be lost and the experiment will Start Over again at zero time or trial #1.
- If you answer *No* by pressing RETURN, the data already collected will not be affected.

Analyze – Leaves EXPERIMENT and goes to ANALYZE DATA.

- Select *Analyze* and press RETURN. If the data has not yet been saved, a warning box will appear. Press RETURN again to clear the data and go to the Main Menu, or press ESC to get another chance to save.
- If the data has already been saved, you will be asked *Are You Sure?*
- If you answer *Yes* by using the ← key and pressing RETURN, the data collected will be transferred into ANALYZE DATA.
- If you answer *No* by pressing RETURN, you will remain in EXPERIMENT and the data already collected will not be affected.

It is important to remember that the maximum temperature must always be larger than than the minimum temperature. If you need to lower both, start with MIN. If you need to raise both, start with MAX. In the Line display the recommended minimum range between MIN and MAX is 5°. In the Bar display the recommended minimum range is 1°. Since the range can be changed as often as desired, it is advisable to start experiments with a large range and narrow it down as needed.

PLAYING WITH SCIENCE: Temperature
ANALYZE DATA



ANALYZE DATA corresponds to the Interpret the Data phase discussed in the Introduction. In ANALYZE DATA students are able to study the data gathered in EXPERIMENT. It can be selected directly from the Main Menu or from EXPERIMENT. The following options are available:

Help – Displays a brief list of the function keys and their uses.

Disk – Contains disk related options, including *Catalog* and *Load*.

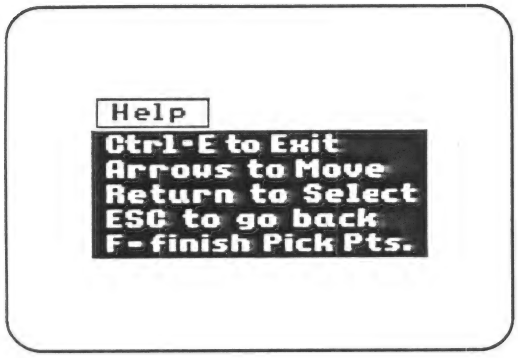
Print – Permits the printing of data in several formats.

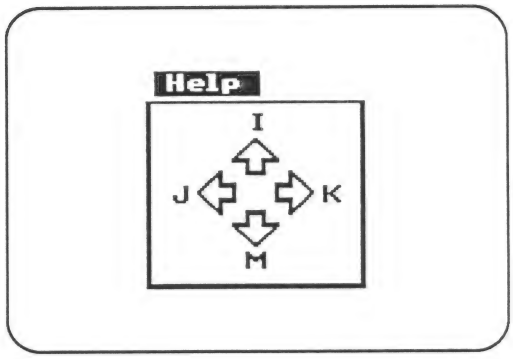
Other – Permits going to the Main Menu or to EXPERIMENT, or restores the displayed data to its original appearance.

Graph – Displays the options for analyzing data. Options include magnification of small data segments and isolation of specific pieces of data.

- Select a menu option by first highlighting it with the arrow keys and then pressing RETURN.
- ESC, the ← key, or the ↑ key can be used to exit from a submenu.
- CONTROL-E can be used to return to the Main Menu.
- For more details on specific keys and their functions, refer to the section on Using the Program, page 12.

Help



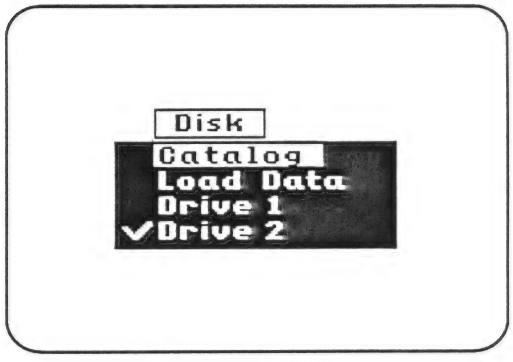


The *Help* option displays a list of useful keys and their functions.

- Select the *Help* option with the arrow keys Press RETURN to display *Help*.
- You can also display *Help* by pressing the ? key.
- Pressing RETURN, ESC, or any arrow key will cause *Help* to disappear.

Actually, there are two *Help* options. The first *Help* option is chosen off the Menu Bar as described above. The other *Help* may be selected while *Zoom* or *Pick Points* (in the *Graph* option) are being used. This *Help* provides key instructions for using these options.

Disk



The *Disk* option offers several disk-related options:

Catalog – Displays a catalog of the files on your data disk. Press RETURN or ESC to exit the catalog.

Load Data – Retrieves data saved during a previous EXPERIMENT session.

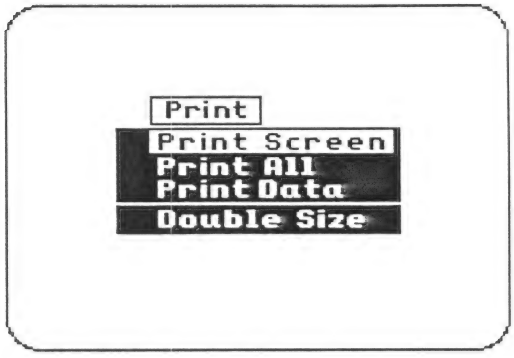
- Use the arrow keys to select a data file from the displayed list of files, and press RETURN. The previously saved data will be retrieved from the disk and displayed on the screen.

Drive 1/Drive 2 – Choose the drive your data disk is in.

- Change the disk drive by highlighting the desired drive and pressing RETURN.
- A √ appears to indicate the selected disk drive.

You will notice that there is no *Save* option provided in the ANALYZE DATA mode. This option is not provided because it is possible to manipulate the appearance of the data in ANALYZE DATA. The integrity of the data is insured by permitting data to be saved only after it is collected in the EXPERIMENT mode.

Print



The *Print* option offers several options for printing out your data:

Print Screen – Prints the graph as displayed on the screen. Press ESC to stop printing if necessary.

Print All – Prints out the entire set of data in the graph format displayed on the screen. Using this option may result in several pages of printouts, so confirmation is required before printing. Press ESC to stop printing if necessary.

Print Data – Prints a text listing of the data collected. Obtain a listing of a subset of the data by using *Pick Points* (in the *Graph* option) first.

Double Size – Causes graph printouts to be doubled in size. Use this option in combination with *Print Screen* to fit an enlarged graph on an 8.5" x 11" piece of paper.

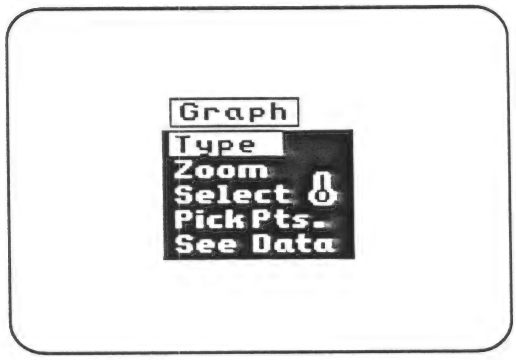
- Turn *Double Size* on by highlighting the option before printing and pressing RETURN. A √ appears to indicate that *Double Size* is selected.
- Turn *Double Size* off by highlighting the option again and pressing RETURN. The √ will disappear.

Other

The *Other* option allows you to return to the Main Menu or to go to EXPERIMENT. In addition, you can select the *Reset* option, which restores the data to its original appearance. By doing so, any changes made to the data during ANALYZE DATA are undone.

- Select *Reset* and press RETURN. Another window will appear asking *Are You Sure?*
- If you answer *Yes* by using the left arrow and pressing RETURN, the data will be restored to its original appearance.
- If you answer *No* by pressing RETURN, the *Reset* option will be canceled and the data will not be restored to its original appearance.

Graph



The *Graph* option offers most of the tools used in ANALYZE DATA. Five options are available:

Type – Display data in either Bar or Line graph format.

Zoom – Enlarge portions of the graph to look more closely at the data.

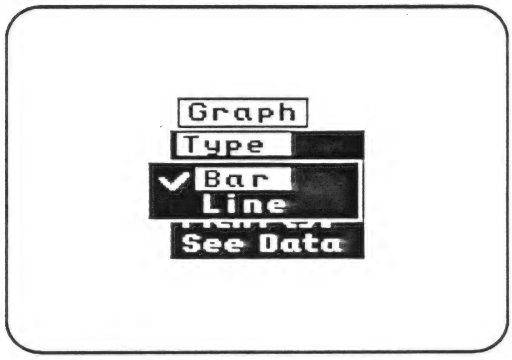
Select Thermistors – Choose which set or sets of thermistor data to display on the screen.

Pick Points – Choose specific data points to be displayed separate from the rest of the data.

See Data – Look at the actual numeric values of the graphed data.

These options are described in more detail in the next several pages.

Type

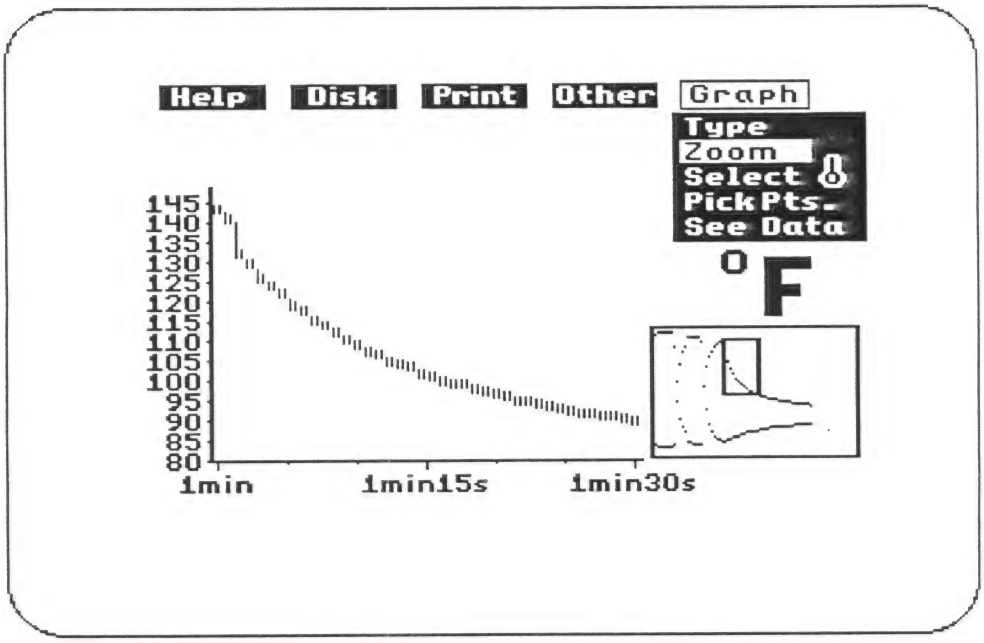


The *Type* option allows the user to display data in either Line or Bar graph formats.

Data collected in the Digital, Thermometer, or Line modes are initially displayed in ANALYZE DATA as Line graphs. Data collected in the Bar graph mode are displayed as Bar graphs.

- Change the display type by highlighting the desired type and pressing RETURN.
- A √ appears to indicate the selected display type.

Zoom



The *Zoom* option allows any segment of the data to be enlarged to fill the entire display area.

The small box on the lower right contains a schematic representation of the entire set of data. Any part of this graph can be enlarged by setting a corner marker and then drawing a box to capture the desired segment of the graph. The schematic set of data in the small box always shows the relationship of the enlarged segment to the total set of data.

The following options are used in *Zoom*:

Set Corner – Positions a reference corner to be used in capturing a segment of the data. *Set Corner* is automatically followed by *Set Size*.

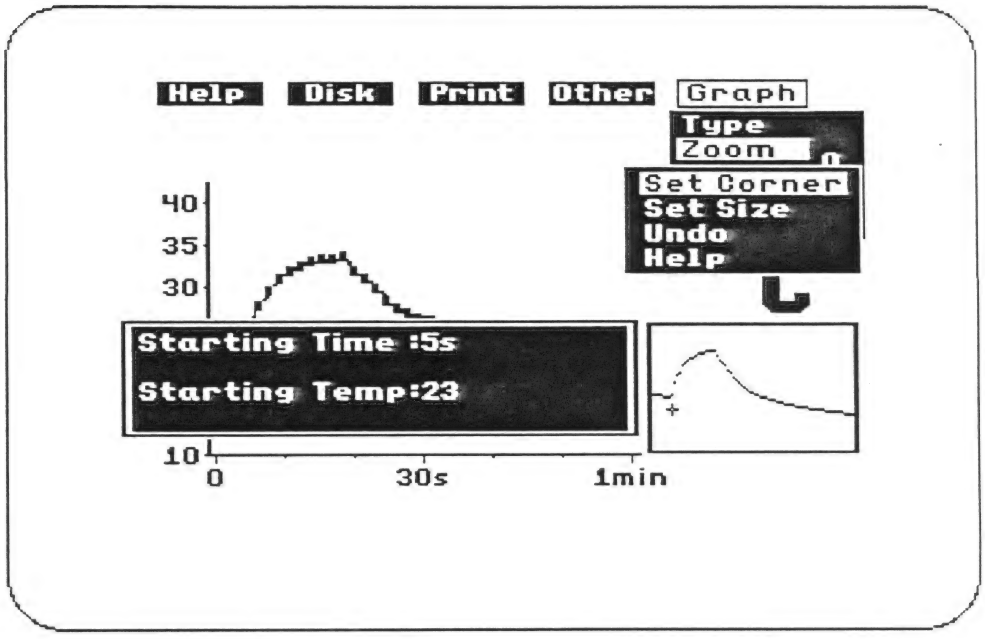
Set Size – Draws a box from the reference corner point to capture a segment of the data.

Undo – Undoes the most recent *Zoom* selection. Restores the data to its most recent previous appearance.

Help – Displays a guide to using appropriate keys.

After using the *Zoom* option, you can restore the data to its original appearance by selecting *Other* off the Menu Bar and then selecting *Reset*.

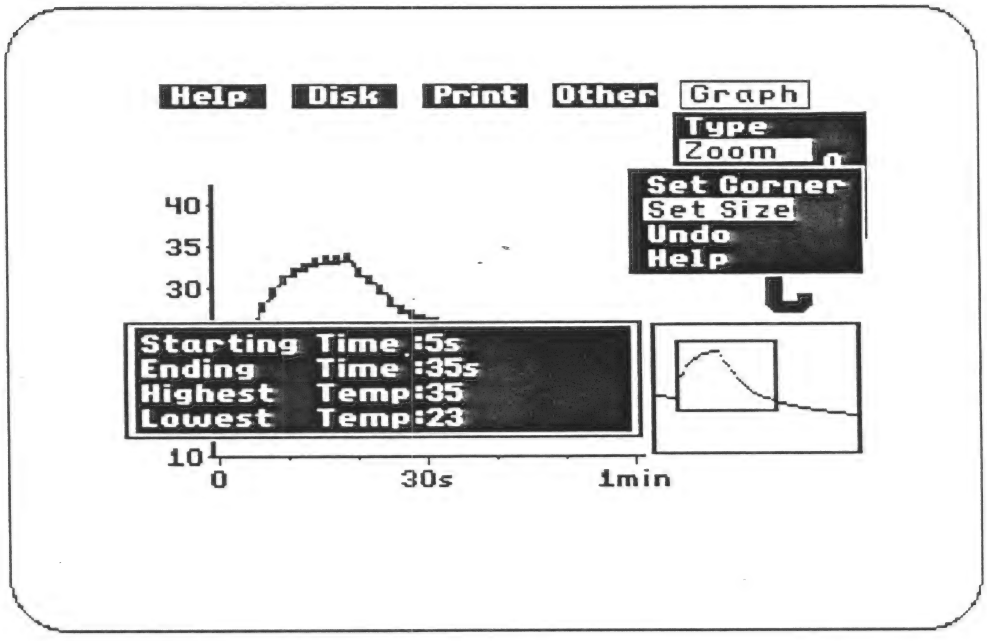
Zoom: Set Corner



Set Corner allows you to specify a corner point for drawing a box to select a set of data to enlarge.

- Select *Set Corner* and press RETURN. A point will appear in the schematic representation of the data in the lower right corner of the screen, and the coordinates of the point are displayed in the window at the left.
- Move the corner point to a desired position on the schematic representation of the data by pressing the arrow keys or the I, J, K, and M keys (for up, left, right, and down). Watch the coordinate values of the corner point change in the window.
- When the corner point is appropriately positioned, press RETURN. You will immediately be required to complete the box with the *Set Size* option.

Zoom: Set Size



Set Size allows you to draw a box from a specified corner point to select a set of data to enlarge.

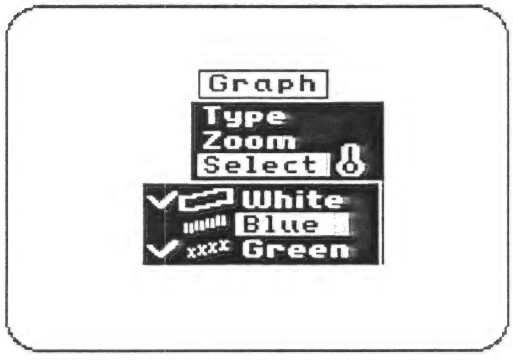
- After using *Set Corner*, *Set Size* is automatically highlighted, allowing you to draw a new box with respect to the new corner point. However, *Set Size* can also be chosen directly. Doing so allows you to modify the size of the current box with respect to the specified corner point.
- *Set Size* displays a window containing both the Temperature range and the Time or Trial range.
- Draw a new box or change the current box by pressing the arrow keys or the I, J, K, and M keys (for up, left, right, and down). The box will appear in the schematic representation of the data in the lower right corner of the screen. Watch the range of values contained by the box change in the window.
- The temperature range, on the vertical axis, may be set in one degree increments.
- When the box is appropriately drawn, press RETURN. The data contained within the box will be enlarged to fill the display screen.
- Once a box of data has been enlarged, the time or trial number changes by regular intervals that are determined by the size of the set of data. The more data contained within the box, the larger the size of the interval between data points.

- The time range of time-based data will correspond to one of the intervals listed below:

15 seconds	3 minutes	20 minutes
20 seconds	4 minutes	30 minutes
30 seconds	5 minutes	1 hour
1 minute	6 minutes	and continuing at
1 min 30 sec	8 minutes	30 minute intervals
2 minutes	10 minutes	

- The range of trial numbers of trial-based data is determined by the number of thermistors being displayed. A maximum of 40 bars can be shown if one thermistor is being studied, while a maximum of 13 sets of bars can be shown if three thermistors are displayed. To increase the number of visible trials, simply decrease the number of thermistors being graphed by using the *Select Thermistors* option.

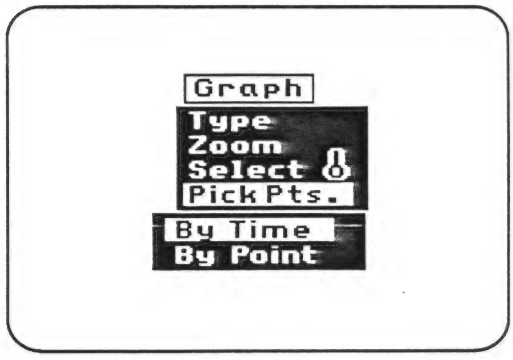
Select Thermistors



When more than one thermistor is used to collect data in EXPERIMENT, it can become difficult to identify the various bars or lines displayed in ANALYZE DATA. The *Select Thermistors* option allows you to select which set of thermistor data to display.

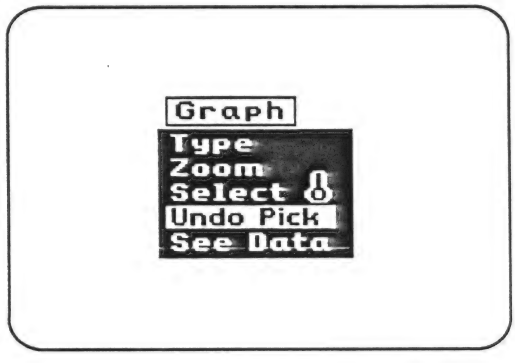
- The data from all active thermistors is displayed when you first use ANALYZE DATA. A √ appears to indicate which thermistors are displayed.
- To stop a set of thermistor data from being displayed, highlight the thermistor to be hidden and press RETURN. The √ indicator will be removed and the thermistor data will be removed from the screen.
- Display a hidden set of thermistor data again by highlighting the desired thermistor and pressing RETURN. The data will reappear on the screen.
- Thermistor data can be selected and hidden as often as desired. Hidden data is always available just by reselecting the thermistor.

Pick Points



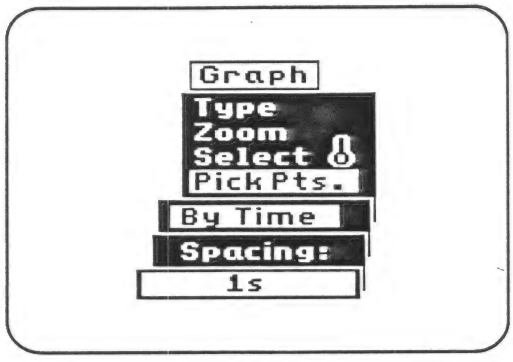
The *Pick Points* option allows you to graph specific data points in order to identify patterns or to discuss specific data values. Using a computer to collect data means that there is a lot of data accumulated. Often it is desirable to eliminate some of this information so that patterns become more apparent. All of the options available in ANALYZE DATA can be used on the data points selected with *Pick Points*.

Pick Points allows you to select data points either *By Time* or *By Point*. *By Time* allows you to specify a uniform time interval between data points. *By Point* allows you to select only those points which you wish to include in the new graph. If your data is time-dependent (taken in Line, Thermometer, or Digital modes), you can select data points either *By Time* or *By Point*. If your data is trial-dependent (taken in Bar mode), you will automatically select data points *By Point*.



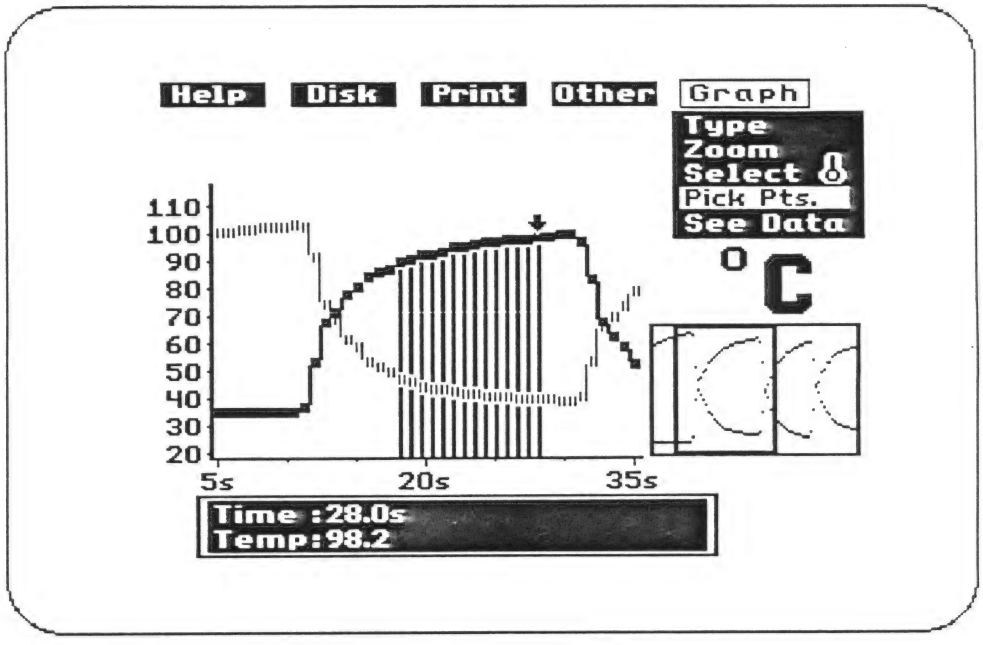
After you have used *Pick Points*, a new option, *Undo Pick*, becomes available. Choose this to restore the data to its former appearance.

By Time:



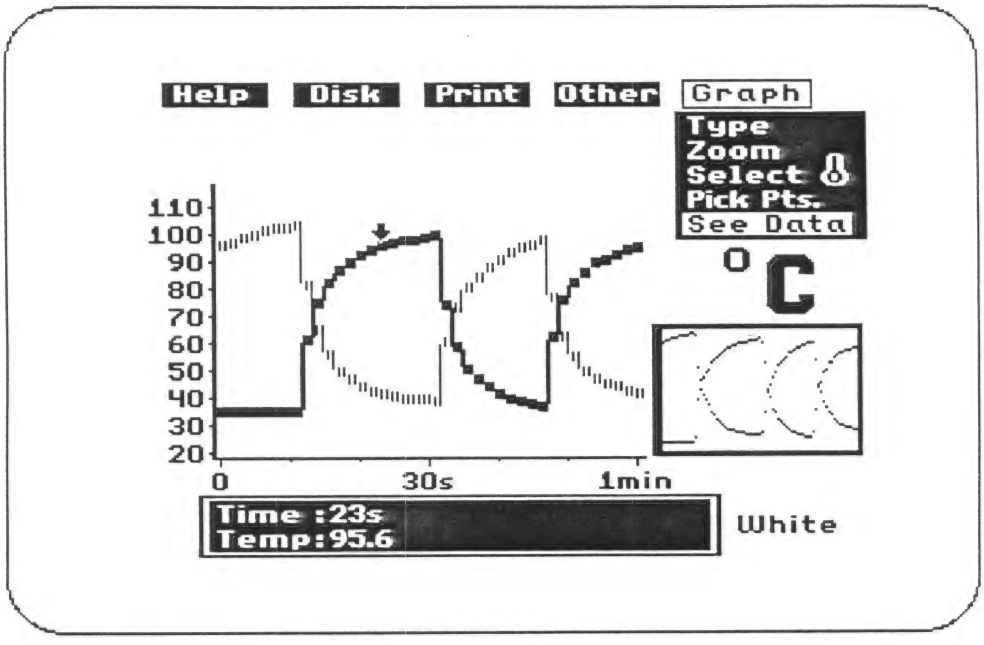
- After selecting *Pick Points*, choose the *By Time* option.
- The program will propose at least two time intervals between data points. Press the → and ← keys to see the alternative time intervals. Press RETURN to accept the time interval displayed.
- The graph will be redrawn displaying as many points as possible within the given time interval, and the *Pick Points* option will be replaced on the menu bar by *Undo Pick*.
- All of the options available in ANALYZE DATA can be used on the data points selected with *Pick Points*.
- *Undo Pick* restores the data to its previous appearance.

By Point:



- After selecting *Pick Points*, choose the *By Point* option. If the graph was in Bar format, it will change to Line format, and a pointer will appear over the first data point. At the bottom of the screen a box identifies the value of the selected data points.
- Use either the →, ←, J, or K keys to move the arrow over the data points you wish to include in your graph. Press RETURN to select each point.
- Use the →, ←, J, or K keys to move the arrow over additional data points. Select as many points as you wish to include. As each data point is selected, a vertical bar appears beneath the point as an indicator.
- Unselect data points by moving the pointer over a selected point and press RETURN. The vertical bar beneath the point will disappear.
- After selecting data points, press the F key. You will see a new trial-based graph using only those data points that you have selected. A new menu option, *Undo Pick*, will appear on the *Graph* option menu.
- All of the options available in ANALYZE DATA can be used on the data points selected with *Pick Points*.
- *Undo Pick* restores the data to its previous appearance.

See Data

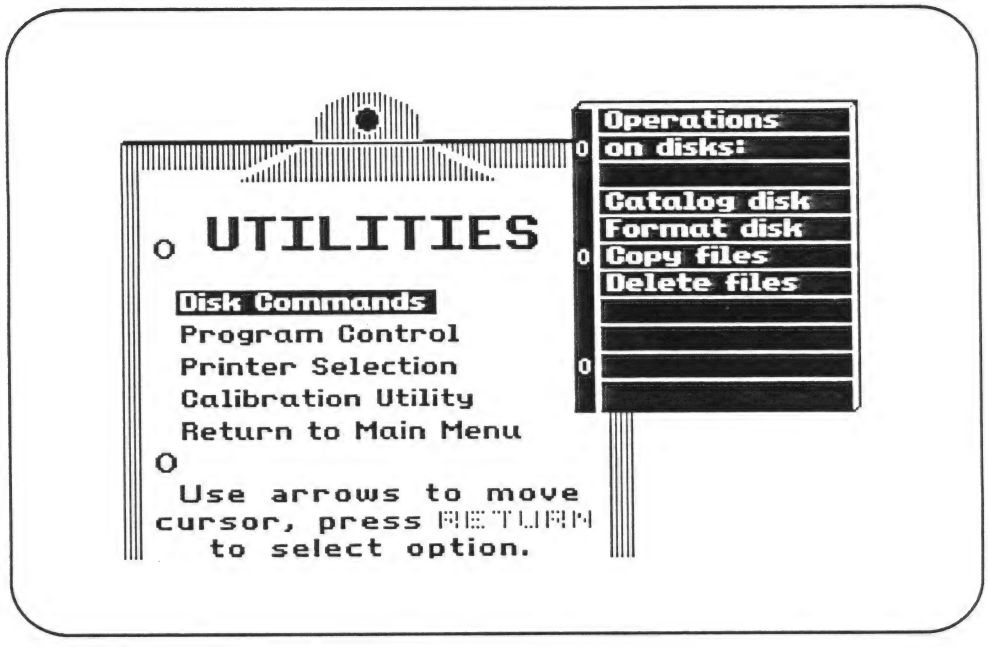


The *See Data* option allows you to look at the actual temperature and time or trial number of any point on the data display.

- Highlight *See Data* and press RETURN. If the data were collected using more than one thermistor, select the thermistor of interest by using the ↓ and ↑ keys to move the highlighter and pressing RETURN.
- A pointer will appear on the left of the large graph, over the first data point of the selected thermistor's graph.
- Use the →, ←, J, or K keys to move the arrow over data points. The temperature and time or trial values of each data point will appear at the bottom of the screen.
- Finish using *See Data* by pressing ESC.

The data display shows up to forty data points at a time. If more data has been collected than can be displayed in the data display, use *Zoom* to enlarge a smaller segment of the data and then use *See Data* again on the enlarged data segment.

PLAYING WITH SCIENCE: Temperature
UTILITIES



The UTILITIES can be accessed by pressing CONTROL-T while the Main Menu or Set-Up Menu is visible. UTILITIES include:

Disk Commands – Options to make data disks, copy and delete files, and set automatic data retrieval.

Program Control – Set program defaults. Specify either Celsius (°C) or Fahrenheit (°F), preset the experiment variables, and suppress the Set-Up Menu.

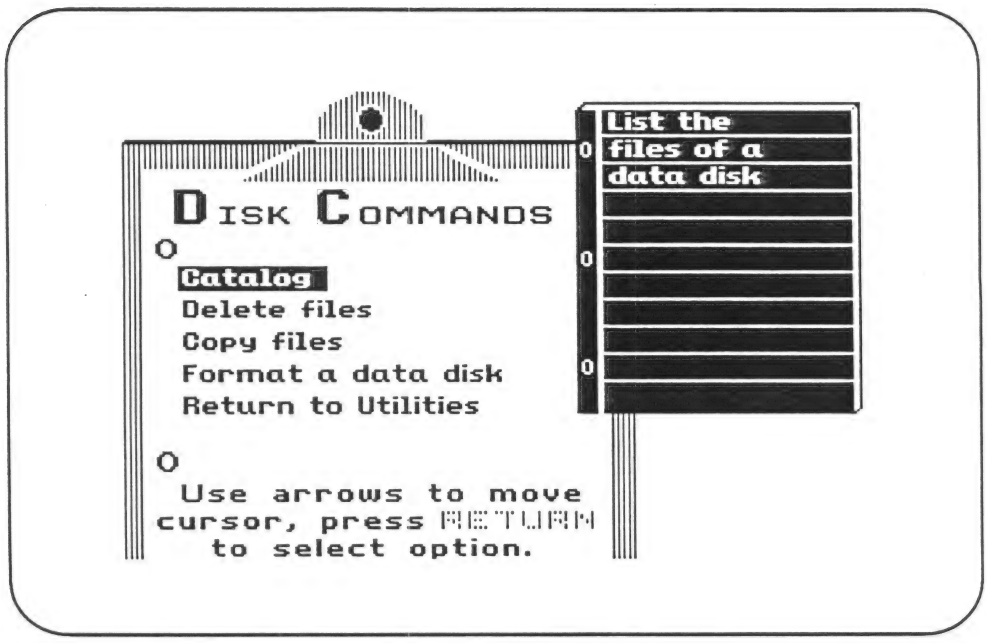
Printer Selection – Select your printer, interface card, and slot #. Enables you to print out your data.

Calibration Utility – Calibrate the thermistors for accuracy.

Return to Main Menu – Finish using UTILITIES and go back to the Main Menu.

- Select a menu option by first highlighting it with the arrow keys and then pressing RETURN.
- ESC can be used to exit from any utility option or to return to the Main Menu.
- CONTROL-E may be used at any time to exit the UTILITIES and return to the Main Menu.
- Type in values as requested. Use the back arrow key to correct mistakes.

Disk Commands



The *Disk Commands* option offers several disk related options:

Catalog – Displays a catalog of the data files on your data disk.

- Use the arrow keys to select Drive 1 or Drive 2 and press RETURN.
- Use the arrow keys to move through the catalog of files if it extends below the box.
- Press RETURN or ESC to exit the catalog.

Delete files – Permits data files to be permanently erased from a data disk.

- Use the arrow keys to select Drive 1 or Drive 2 and press RETURN.
- Use the arrow keys to select a data file from the displayed list of files, and press RETURN.
- Use the arrow keys to highlight *Yes* and press RETURN. The selected file will be erased from the data disk.
- Press ESC or answer *No* to *Are You Sure?* to cancel this option.

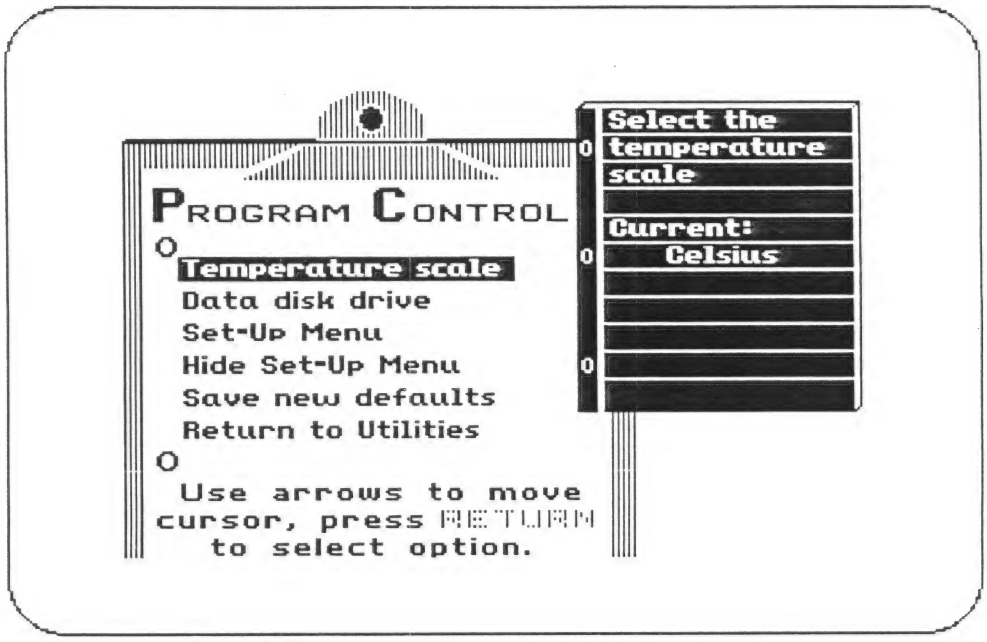
Copy files – Permits data files to be copied from one data disk to another.

- Select the disk drive for the source data disk and press RETURN.
- Select the disk drive for the target data disk and press RETURN.
- Use the arrow keys to highlight data files on the displayed list of files. Use the SPACEBAR to mark files to copy. Press RETURN when you have finished marking files.
- Follow the prompts on the notepad for swapping disks, if necessary.

Format a data disk – Prepares blank disks for use as data disks. Old disks can be erased and used as data disks as well.

- Use the arrow keys to select Drive 1 or Drive 2 and press RETURN.
- Check the disk to be sure you have one you wish to erase in the selected drive. Answer *Yes* when you are ready to continue.
- The formatting procedure will take about 30 seconds.

Program Control



The *Program Control* option allows customizing **PLAYING WITH SCIENCE: Temperature** for specific audiences.

Temperature Scale – Specify either Celsius (°C) or Fahrenheit (°F).

- Switch between the two temperature scales by pressing the ← or → keys. Press RETURN to accept.

Data Disk Drive – Specify the default data disk drive.

- Use the arrow keys to highlight the desired drive number. Press RETURN to accept.

Set-Up Menu – Set the Set-Up Menu defaults, which can then be saved on disk as new defaults.

- See the additional description of this option on page 48.

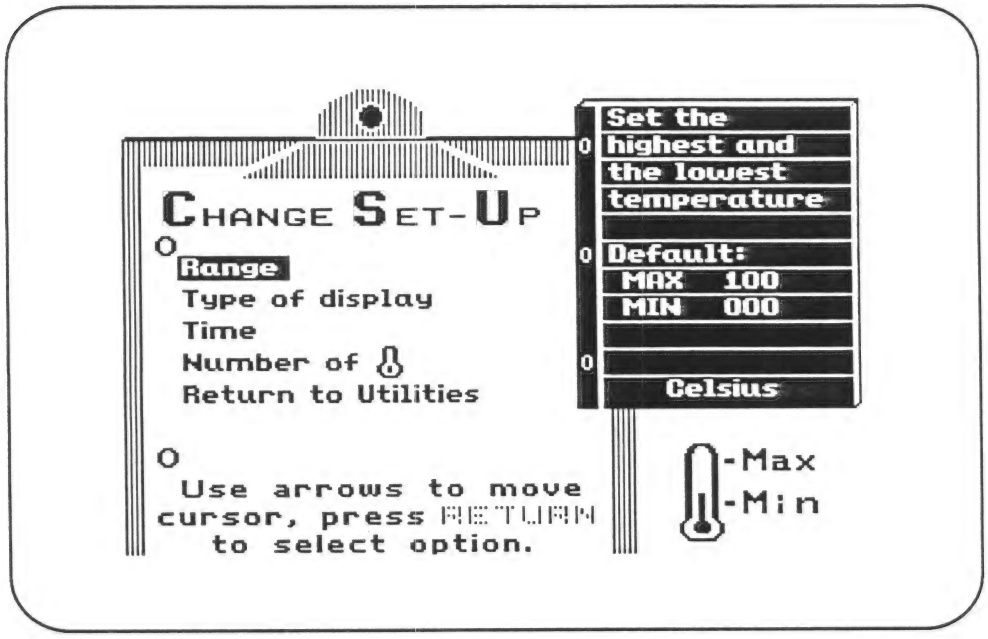
Hide Set-Up Menu – This option suppresses or permits the appearance of the Set-Up Menu after DO AN EXPERIMENT is selected on the Main Menu. If this option is set to *Hide Menu*, the Set-Up Menu will not appear and students will go directly to EXPERIMENT, with the current defaults determining the *Range*, *Type of display*, *Time*, and *Number of thermistors*.

- Highlight the option and press RETURN.
- Use the arrow keys to switch between *Show Menu* and *Hide Menu*. Press RETURN when the desired selection is shown.

Save New Defaults – Saves the new program defaults on the program disk.

- Use the arrow keys to highlight this option. Press RETURN to save default values as presently set.
- If the new defaults are not saved, the altered defaults will only be available during the current session at the computer.

Change Set-Up Menu



This section of the UTILITIES is a duplicate of the main Set-Up Menu. Values set here become defaults until the computer is turned off, or can be saved as new defaults by selecting that option on the *Program Control* menu.

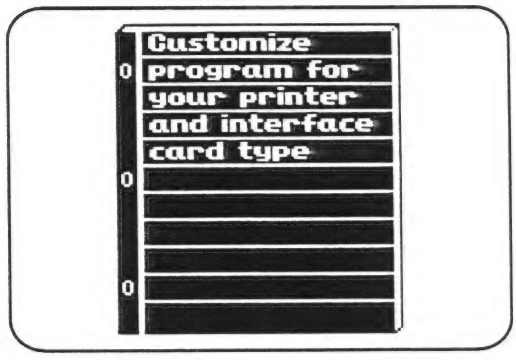
Range – Specify the temperature range that will be displayed while collecting data. The range is determined by setting both the maximum and minimum temperatures to be displayed.

Type of display – Specify in what format the data will be displayed. Line, Thermometer, and Digital collect and display data continuously, while Bar permits the collection of data in individual trials.

Time – Specify for how long data is to be collected.

Number of thermistors – Specify how many thermistors to use in the experiment.

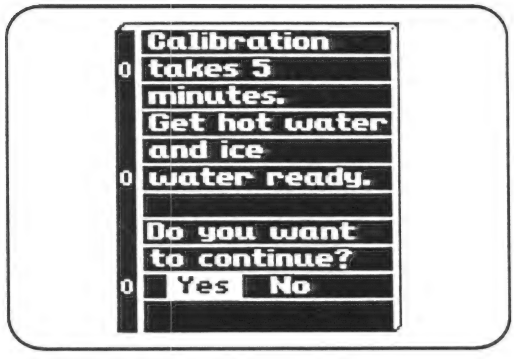
Printer Selection



In order to print out graphs and data lists, the type of printer connected to the computer must be specified. The interface card and its slot number are also requested.

- After a brief pause while printer options are loaded in, the current printer and interface settings are displayed. If you do not wish to change the printer set-up, respond *N* to the prompt, and you will return to the UTILITIES menu.
- If you do wish to change the settings, respond *Y* and use the arrow keys to scroll through the list of available printers. If your printer is not on the list, try selecting one that you know is similar or one made by the same company. When the correct printer is highlighted, press RETURN to select it.
- Scroll through the list of interface cards and select the appropriate one by pressing RETURN when it is highlighted.
- Press RETURN to specify slot 1 or type in the correct number if you wish to use a different printer card slot.
- If all options are now correct, respond *N* to the prompt to return to the UTILITIES menu.

Calibration Utility



Calibrating thermistors is a time-consuming but simple task. It need only be done once if you will be using only one computer with one set of thermistors. If the equipment is to be shared among several computers, you may wish to calibrate the thermistors whenever a different computer is used. Calibrating thermistors guarantees that the three thermistors will respond with similar readings when held at the same temperature. It also improves the accuracy of the measurements.

- Select *Calibration Utility* with the arrow keys and press RETURN. Follow the prompts that appear on the notepad.
- You will need a bowl filled with hot water (about 80°C or 175°F), a bowl filled with ice water (about 4°C or 40°F), and a standard thermometer. If this equipment is available, respond *Y* to the prompt and continue. If not, respond *N* to the prompt.
- Follow the directions on the notepad carefully to insure that the calibration is done correctly. It takes about 3 minutes for the thermistors to become really stable in each temperature bath, so be prepared to wait until the program tells you to continue.
- After successfully completing the calibration, you are prompted to save the calibration on the **PLAYING WITH SCIENCE: Temperature** disk. If for some reason the calibration was interrupted or unreliable, answer *No* or press ESC to avoid saving the new calibration information.

PLAYING WITH SCIENCE: Temperature ACTIVITIES

Overview

Conducting guided-discovery experiments in a classroom setting requires some willingness on the part of the teacher to allow students to become actively involved in their own learning process. The activities that follow, and their corresponding activity sheets, are set up to support a framework for discovery learning while providing the teacher with a structured approach to science teaching.

The activities are grouped into six major categories. Within each group are from 3 to 7 different experiments and demonstrations, roughly in order of difficulty. Most of these experiments are designed to be easily performed in a 30 to 45 minute class period.

Briefly outlined, the major categories of activities are:

Group 1: **Playing with Hot and Cold!** Simple explorations into the meaning of the vocabulary of temperature, suitable for use with children of all ages. What is a thermometer, how do thermometers work, and how good are we as thermometers are some of the questions asked.

Group 2: **Learning about your body.** These questions explore our ability to detect temperature changes, and develops the idea of sensory adaptation. Human and machine are compared, and the limitations of both are discovered.

Group 3: **Why do things get warmer?** By exploring how heat travels from place to place, students begin to understand how energy can be transformed and how heat can be detected. Experiments on retaining warmth and on how to dress in warm and cold weather provide practical examples on how important understanding heat transfer can be.

Group 4: **Learning about sunshine.** As the biggest object around and certainly something everybody knows about, this heat source deserves investigation. By using it as a convenient energy source, sunlight can be explored and some of its effects on our earth investigated.

Group 5: **Learning about water.** With 3/4 of the earth's surface covered with water, and most of the human body made of this substance, understanding how it behaves when the temperature changes is both important and useful.

Group 6: **Coffee cups and temperature,** an investigation in consumer chemistry. These experiments center around the highlight of the teacher's life, the coffee break. While exploring the effects of heat loss and controlling variables, your students will learn to make better consumer decisions and even help you enjoy your coffee more.

Each classroom lesson plan has a similar structure. On the first page you will find the following sections:

Question: This question provides a theme for the lesson, and is designed to interest students in exploring the specific concept areas of the lesson.

Grade level: Suggested grade level. Materials suitable for younger students usually require one computer and a large monitor. Older students are challenged to explore the topic themselves by following directions and answering questions on the provided activity sheets.

Equipment needed: A list of recommended equipment. Unless noted, most required materials (except the software and the computer) are normally found in the standard classroom.

Concepts: This is a short list of the scientific basis for the lesson. While not exhaustive (some lessons have alternative concepts that depend on teacher interest and knowledge), this list will help you quickly identify the major ideas needed to understand the science involved in that lesson.

Objectives: These statements can be used to evaluate learning, and student progress. Again, they are not exhaustive, but provide a quick list against which you can determine the usefulness of the lesson for your particular classroom situation.

General description of the experiment: These brief descriptions of the experiments will help you decide which activity will most interest your students.

A complete step-by-step plan for a **Classroom lesson** follows. Suggestions for one-computer classrooms or multi-computer labs are included in this section. Discussion topics and interesting questions that extend the application of the science concept under investigation are also found here. At the end of the **Classroom lesson** are teacher-oriented essays that contain helpful information. **Getting the idea** helps develop the concepts explored in the activity. Under **Expanding the idea** are suggestions for related topics that can be researched by older students, supplementary experiments that explore more advanced or slightly different topics, and references to other activity sheets that investigate related concepts.

At the end of most of the lesson plans are **Activity sheets.** These sheets are intended to be duplicated and handed out to students. They contain instructions for setting up the computer, on getting print outs if necessary, and questions for students that require them to apply the investigated concepts. In some cases, several activity sheets are provided, designed for use with different age groups or ability levels.

USING THE MATERIALS

Read through the Classroom Lesson Plan. Decide if you will be using one computer or several and set up the classroom appropriately. Read through the activity sheets and use white paper to cover any sections that you feel will not be appropriate for your students. Copy the activity sheets as needed. Gather the materials required, and before your students arrive, run through the experiment quickly to make sure that everything is working properly. After students have completed the activity, have them carefully put away all equipment. Thermistors should be rinsed and dried before they are put away.

SAFETY

While all the experiments described have been designed to minimize the possibility of danger, there is always the possibility of accidents. Students should be reminded before every activity that water and computers don't mix, and under no circumstances should water be poured or spilled over a computer. Styrofoam cups are often very unstable; coffee cups from home make excellent containers. Use of inexpensive aluminium baking pans to hold cups of water will avoid the possibility of having spilled liquids wetting the computers.

A first-aid kit should be available in the classroom, and students should know its location. A fire extinguisher designed for use with electrical fires is also recommended. When working with glassware, students should be given extra instructions to avoid accidents. While there are no dangerous chemicals involved in any of the Classroom Lesson Plans, it is best to warn students never to put anything in their mouths. Thermistors should not be put in mouths, and they should never be chewed or bent so as to create broken wires. Any spills should be cleaned up immediately. Students should be encouraged to be responsible for cleanup when activities have been completed. Water should be disposed of properly, cups washed out, and thermistors cleaned and dried.

Emphasize the necessity for care and good behavior during science activities, both to maximize effective learning and to minimize the chance of accidents. If you have any concerns about the safety of doing an activity, DO NOT DO THE EXPERIMENT. If you are working in a standard classroom, consider only doing the activities as demonstrations, and devote the major amount of time to the suggested classroom discussions and to student analysis of the graphs.

Activities by Suggested Grade Level

Activities	K	1	2	3	4	5	6	7
1-1	√	√	√	√				
1-2	√	√	√	√				
1-3	√	√	√	√	√	√		
1-4	√	√	√	√				
1-5	√	√	√	√	√	√		
2-1	√	√	√	√	√	√	√	√
2-2		√	√	√	√	√		
2-3		√	√	√	√	√		
2-4				√	√	√	√	
3-1	√	√	√	√				
3-2	√	√	√	√	√	√		
3-3	√	√	√	√	√	√	√	√
3-4				√	√	√	√	√
3-5	√	√	√	√				
3-6			√	√	√	√	√	√
3-7				√	√	√	√	√
4-1	√	√	√	√				
4-2	√	√	√	√	√	√		
4-3				√	√	√	√	√
4-4				√	√	√	√	√
4-5			√	√	√	√	√	√
4-6		√	√	√	√	√	√	√
4-7					√	√	√	√
5-1		√	√	√	√	√		
5-2				√	√	√	√	√
5-3		√	√	√	√	√		
5-4					√	√	√	√
5-5					√	√	√	√
5-6					√	√	√	√
5-7				√	√	√	√	√
6-1				√	√	√	√	√
6-2				√	√	√	√	√
6-3				√	√	√	√	√

Activities by Standard Topic

Activities	Thermometers	Earth Science	Chemistry	Energy	Control of Variables	Human Physiology	Reading and Interpreting Graphs	Light and Heat	Weather
1-1	√					√			
1-2	√			√					
1-3	√					√			
1-4				√				√	
1-5	√						√		
2-1	√			√		√	√		
2-2						√			
2-3						√	√		
2-4						√			
3-1				√	√		√	√	
3-2				√	√		√	√	
3-3		√		√	√		√	√	
3-4		√		√	√		√	√	
3-5					√	√	√		
3-6		√		√	√		√		√
3-7				√	√	√		√	√
4-1		√		√	√		√	√	√
4-2		√		√	√		√	√	√
4-3		√		√	√		√	√	
4-4		√		√		√		√	√
4-5		√		√	√		√	√	√
4-6		√		√		√	√	√	√
4-7				√				√	√
5-1	√				√	√		√	
5-2	√				√		√	√	
5-3			√		√				
5-4			√	√	√		√		
5-5			√	√	√		√		
5-6		√	√				√		
5-7			√	√	√		√		
6-1			√		√		√		
6-2			√		√		√		
6-3			√		√		√		

Classroom Lesson Plan 1-1
Playing with Hot and Cold!

Question 1-1: How does a thermometer work?

Grade level: K–3

Equipment needed:

- A pitcher full of ice cold water, the ice removed.
- A large 3 quart (3 liter) bowl containing 1 quart (1 liter) of warm tap water.
- Standard school thermometer.
- *Optional:* **PLAYING WITH SCIENCE: Temperature** with the white thermistor.
- Activity Sheets 1-1C or 1-1F prepared as instructed on the sheet.
- Copies of Activity Sheet 1-1 for your entire class.

Concepts:

- Temperature is a measure of the amount of heat energy an object has.
- Thermometers are instruments for measuring temperature.
- Instruments are often used to extend our senses.

Objectives:

The students will be able to:
- Distinguish between Thermometer and Temperature.
- Discuss the inaccuracy of a hand as a temperature measuring device.

General description of the experiment:

We often use instruments to extend our senses without being really sure why they are necessary. In this activity, students place their hands in warm water that is gradually cooled by the addition of cold water. If the cold water is added slowly enough, students can only tell when the temperature changes by more than 10°. A thermometer is used to monitor the temperature so that students can easily see that the temperature does indeed change, even if their hands are not sensitive enough to feel the change. If **PLAYING WITH SCIENCE: Temperature** is used with a large monitor, the entire class can easily see the delay between the temperature change and the perception of that change.

Classroom lesson:

1. Start by emphasizing the difference between THERMOMETER (something we measure Temperature with) and TEMPERATURE (the thing we actually measure). The cut-out Thermometers on Activity Sheets 1-1C and 1-1F can be used to illustrate the discussion.

2. Define Temperature in operational terms as simply how hot or cold something is. This is a perfectly good definition for young students. Don't confuse temperature with the amount of heat energy something has. Heat energy depends both on temperature and the amount of material involved. A large hot-water bottle has more heat energy, at the same temperature, than a tiny one.

3. Have your students make lists of hot things, cold things, and lukewarm things. You might use this opportunity to have students touch many different objects, trying to determine their relative temperature. Let them use terms as warm, cool, hot, and cold. Caution students about touching very hot objects.

   Letting students form their own lists is a very useful organizational activity, fundamental to the study of science.

4. On the blackboard, put a copy of the chart found on Activity Sheet 1-1. Hand out copies to every student so that they can have their own record of the experiment.

5. Put the bowl of warm water in front of the classroom. Place a thermometer in the bowl. Choose one student from the class to place a hand in the water beside the thermometer. Have the student describe the temperature of the water in terms such as hot, very hot, etc. Record the actual temperature of the water and the student's description in the space provided on Activity Sheet 1-1.

6. Without the student's looking, very gradually add about one-quarter of a cup of cold water to the bowl. Again have the student describe the temperature of the water. Was there a noticeable change? Record the results on Activity Sheet 1-1.

7. Continue adding quarter cups of water, one at a time, maintaining a temperature drop of 2° to 5° if possible. After each addition, record the student's description of the temperature of the water on Activity Sheet 1-1. Again, require students to use comparative terms, cooler, no change, warmer, very cold. After ten or more repetitions, the temperature should have dropped more than 30°, a very significant change.

8. If time permits, students can make their own thermometers from Activity Sheets 1-1C and 1-1F. Coloring them with crayons or markers will help students personalize them. Have students take these home and place them near the breakfast table. You might ask them to move the thermometer to record the morning temperature each day for a week as an at-home activity.

9. You may want to use **PLAYING WITH SCIENCE: Temperature** instead of a thermometer. Connect the computer to a large monitor so that the whole class (except the student with a hand in the water) can see. Select DO AN EXPERIMENT from the Main Menu. Set the Set-Up options as follows:

Range:	MAX	50°C	(130°F)
	MIN	0°C	(32°F)
Type of display:	Thermometer		
Time:	15 minutes		
Number of thermistors:	1		

Select EXPERIMENT and press RETURN to begin taking data. Now do Steps 5, 6, and 7.

The advantages of using **PLAYING WITH SCIENCE: Temperature** in this case are that the large numbers can easily be seen by every student in the class and that it is not necessary to remove the thermometer from the water in order to read the temperature.

Getting the idea:

Discuss with the students how we often use instruments to help us when our senses are not good enough to record the information we are interested in. In this experiment, the relative insensitivity of our skin is clearly demonstrated. If the cold water is added slowly enough, the temperature change will be very large before it can be felt. Since we tend to take our feelings as correct without really thinking about it, this can be very surprising.

Students may feel that the person whose hand was in the water was at fault in misjudging the water temperature. If this happens, repeat the experiment with other students. The results will be very similar.

The students will also run out of words to describe the changes they do detect. This an excellent opportunity to discuss why measurement in general is so important. Communication is much easier when there is an absolute definition for a term and while one can argue about the meaning of 'warm', 25°C has a very definite meaning. A good way to emphasize the importance of absolute terms is by slowly moving through the year, talking about average temperatures as you go. When you talk about a warm summer day, you move the cut-out thermometer up to 25°C (80°F). When you talk about a cold winter day, move the thermometer down to 0°C (32°F). In the spring or fall, it might be 15°C (60°F). Discuss why we think of spring as warmer than fall, even though the average temperature is the same.

If you plan to spend some time discussing units of measurement, now is a good time to mention the difference between °C and °F. It is important that students understand that neither system is more accurate or better than the other. They are simply different, with Celsius being a bit more convenient to use since it is based on 10's.

Expanding the idea:

Have older students look up Robert Boyle, Gabriel Daniel Fahrenheit, Baron William Thomson Kelvin, Anders Celsius, and Galileo Galilei. What did each of these men contribute to the measurement of temperature?

Have your students create their own thermometers. It is possible to buy unmarked thermometers from some supply houses, or simply tape over the numbers on your marked thermometers. Use boiling water and ice water to identify two absolute points on the scale, and then decide how many other intervals to use.

PLAYING WITH SCIENCE: Temperature has a calibration utility, found in the Utility menu (use Control-T to access this from the Main Menu). Older students can be asked to calibrate the thermistors by following the provided directions. Questions to ask after they have completed this optional activity include:

- Does this step make a difference in the accuracy of the thermistors?
- In the computer's ability to determine temperature?
- What other reasons are there for doing a calibration before doing an experiment?

Activity Sheet 1-1
Playing with Hot and Cold!

Question: How does a thermometer work?

Gathering the data:

Step 1) Get a standard thermometer and place it in a bowl filled with one quart (1 liter) of very warm water.

Step 2) Have a student put a hand in the bowl of water and look away. The student should not look at the bowl for the entire experiment.

Step 3) As you slowly add one-quarter of a cup of cold water to the bowl, record the temperature of the water, and the impression of the student who's hand is in the bowl. Use terms such as hot, very hot, warm, etc.

Temperature as MEASURED (Thermometer)	Temperature as OBSERVED (Student)

Step 4) Mark the temperatures where the change was noticeable. How many major changes were there? _____

Thinking about the results:

Step 5) Which is more sensitive to change – the thermometer or your hand?

_____

_____

Can you suggest some reasons for the difference?

_____

_____

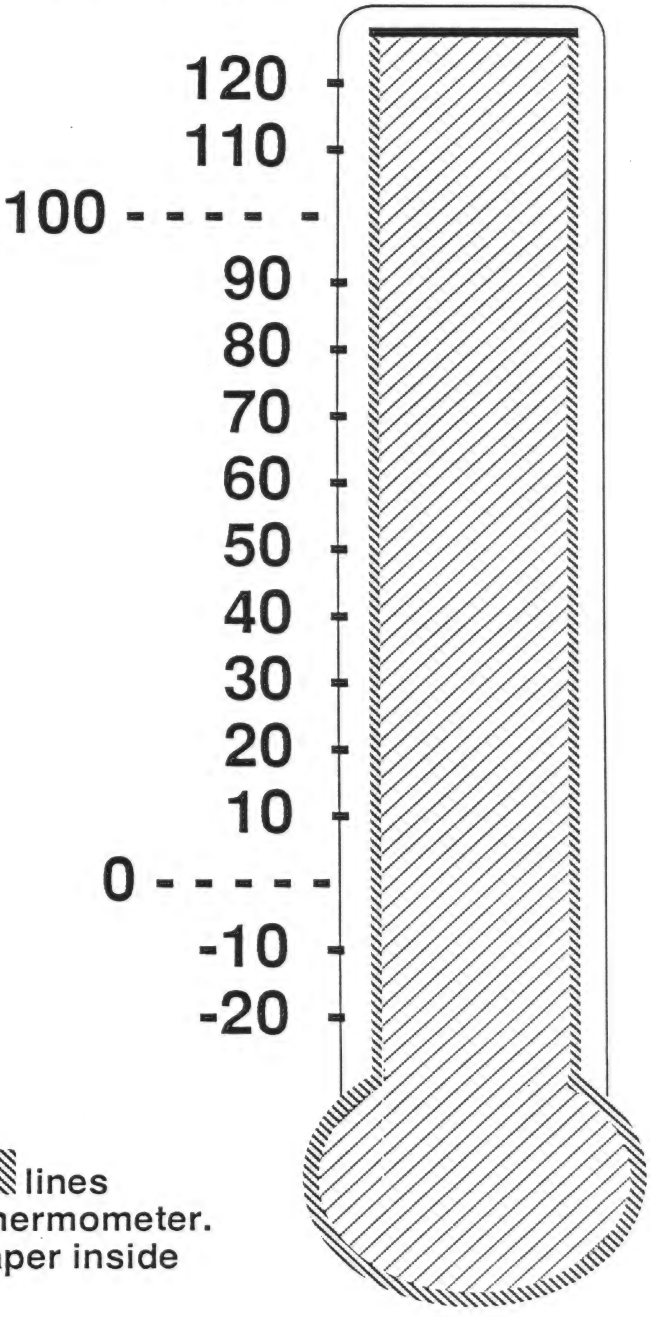
_____

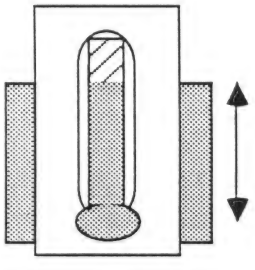
_____

Sunburst Communications © 1988

Activity Sheet 1-1C
Make Your Own Thermometer

Temperature °C



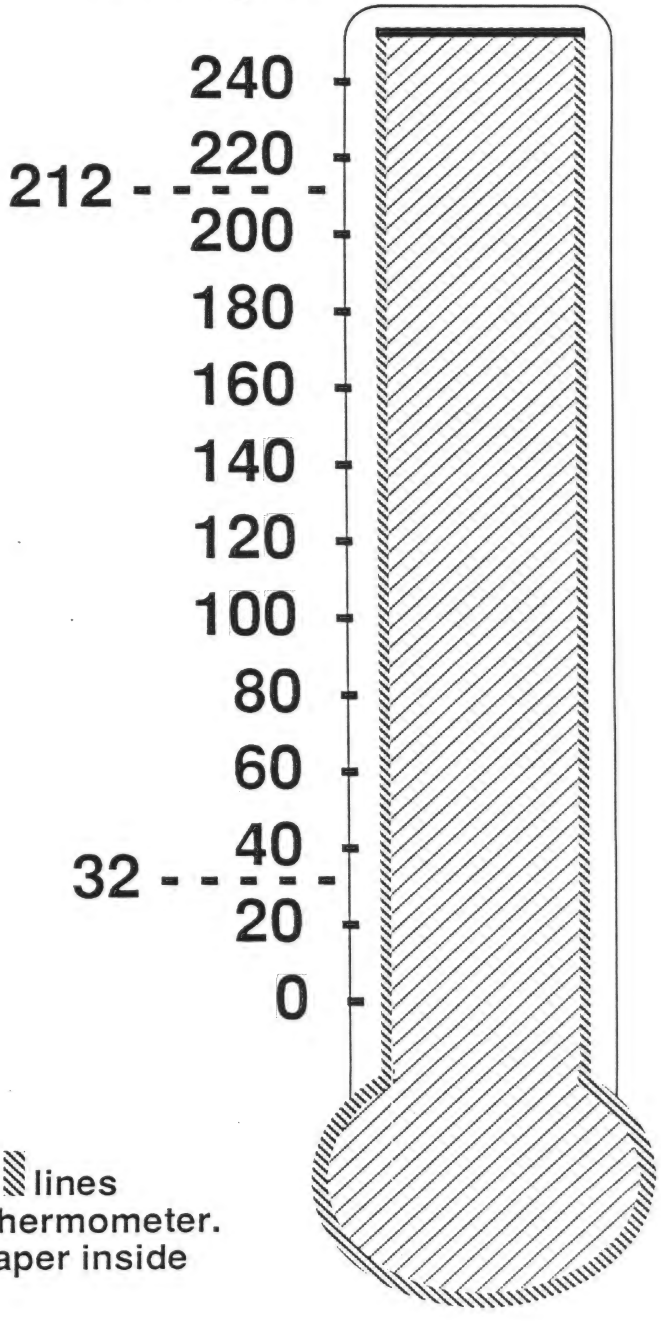


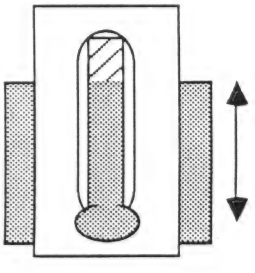
Cut along the striped lines on both sides of the thermometer. Slide a piece of red paper inside of the thermometer.

Sunburst Communications © 1988

Activity Sheet 1-1F
Make Your Own Thermometer

Temperature °F





Cut along the striped lines on both sides of the thermometer. Slide a piece of red paper inside of the thermometer.

Sunburst Communications © 1988

Classroom Lesson Plan 1-2
Playing with Hot and Cold!

Question 1-2: Why does the liquid in a thermometer rise when the temperature rises?

Grade level: K-3

Equipment needed:

- Four or five students.
- Clear floor space, about 3 meters (10 feet) long.
- Masking tape or chalk to mark the floor.

Concepts:

- Liquids are made up of discrete particles called molecules.
- Increasing the temperature of a liquid makes the molecules move faster.
- Faster moving molecules take up more space, causing liquids to expand.

Objectives:

The students will be able to:

- State that liquids are made up of particles.
- State that as liquid particles move faster they take up more space, making the liquid in a thermometer rise.

General description of the experiment:

Students are lined up on a floor while they are standing still, and the space they take up is measured. They are then asked to pretend that they are being heated by starting to turn around rapidly, maintaining minimum spacing without hitting each other. The space taken up necessarily increases. This simple but effective demonstration helps young students visualize what happens inside a liquid when the temperature increases according to the kinetic theory of liquids. If you wish to discuss this theory of heat, this activity provides a simple way of introducing the idea.

Classroom lesson:

1. Start the discussion by reviewing what happens to a thermometer when the temperature increases. Use the paper thermometers made earlier (Activity Sheets 1-1C or 1-1F) or the Thermometer display of **PLAYING WITH SCIENCE: Temperature** to make the concept more concrete.

2. Have four or five students line up in a clear spot on the classroom floor. Use masking tape or chalk to draw two parallel lines, one on each side of the line of students. Let the line extend past the end of the students by a good amount. Tell them that the lines represent the sides of the thermometer, and they are not allowed to go outside of these lines. They can move up the 'tube' if necessary, however.

3. Mark off the top of the line with chalk. Tell the class that the line of still students represents the particles or molecules of a liquid that is cool.

4. Now, explain that increasing the temperature means that the molecules will begin to move faster. Have students start spinning very slowly in place. Have them move farther apart as necessary to avoid touching each other.

5. After a minute or so, have them stop in place, and draw their attention to how far up the parallel lines they have moved. You can have them repeat this at gradually increasing speeds. As the speed of spin increases, they will have to move farther apart, duplicating the motion of the alcohol or mercury in a thermometer.

Getting the idea:

Every substance is made up of molecules. Introduce this concept without defining it in detail, unless you are prepared to spend quite a bit of time on this one topic. For this demonstration, students only need to know that molecules are tiny particles that make up all substances, with no more explanation.

In the kinetic model, when molecules are heated, they gradually begin to move more and more rapidly, and since they cannot touch, the distance between them increases. This increasing distance causes a slight amount of expansion to occur.

Thermometers are specially designed to amplify this effect. Have your class look closely at several thermometers. They all have large round bulbs at the bottom that contain lots of liquid. When this large amount of liquid expands, it is forced to do so by moving up a very, very narrow tube. Thus a slight expansion of the liquid in the bulb results in enough motion in the tube to be visible to the naked eye.

Different liquid can be used in thermometers, the most popular being mercury (silver) and alcohol (red). Both of these liquids will expand in a linear manner, making them easy to calibrate. They also stay liquids at the temperatures that the thermometers are likely to be asked to measure. Water is not used in thermometers because it freezes at 0°C (32°F) and boils at 100°C (212°F), common temperatures to measure.

Expanding the idea:

Have your students report on other kinds of thermometers in common use. For example, bimetallic strip thermometers are commonly used in home thermostats. Older students might want to look up an optical pyrometer, a thermometer that uses the color of the light radiated from a very hot object to determine its temperature.

Have your students make a list of thermometers found around their home, and what they are used to measure. Most homes have at least three different thermometers, one on the thermostat, one in the bathroom (a fever thermometer), and one in the oven to measure oven temperature.

If your students have any fever strips (liquid crystal thermometers), have them bring them into the classroom. These are made by putting temperature sensitive chemicals (liquid crystals) inside of a thin plastic envelope. They work because the chemicals change color as they change temperature. Ask your students if they have seen any other examples of this technology. If possible, obtain a mood ring or other example of this technology to pass around the classroom during the discussion.

Classroom Lesson Plan 1-3
Playing with Hot and Cold!

Question 1-3: What do we mean by hot, cold, and lukewarm?

Grade level: K-5

Equipment needed:

- One set of five bowls for every group doing this experiment. Each bowl in each set must be labeled with a different symbol or a different letter.
- Pitchers of hot and cold water. Hot tap water works well. The cold water should be ice cold with the ice cubes removed.
- If you are working with older students, you will need enough copies of Activity Sheets 1-3A and 1-3B for each student.
- **PLAYING WITH SCIENCE: Temperature** with the white thermistor.
- *Advanced Investigation only*: Copies of Activity Sheet 1-3C for each student.

Concepts:

- The same substance can have many different temperatures.
- Our hands are sensitive only to large differences in temperature.
- We use a specific vocabulary when dealing with temperature, but the words are relative to the surrounding conditions.
- We must use tools such as thermometers to give real meaning to the words hot, cold, etc.
- *Advanced Investigation only*: When left alone, warm things tend to cool down and cool things warm up. Eventually most things will reach room temperature.

Objectives:

The students will be able to:
- Place objects in order of increasing or decreasing temperature.
- State that words such as hot, cold, and lukewarm are relative terms.
- Use **PLAYING WITH SCIENCE: Temperature** to measure the temperature of various liquids.

General description of the experiment:

Students must put five bowls containing water of different temperatures in order by temperature, using their hands as measuring instruments. Once this has been done, the **PLAYING WITH SCIENCE: Temperature** is used simply to check their results. 20 minutes later, they are asked again to place the bowls in order. Since the hot water has cooled and the cold water warmed up, this time the task is more difficult, and the use of an instrument like **PLAYING WITH SCIENCE: Temperature** is more important. Room temperature is also discussed.

Classroom lesson:

1. Talk about the meanings of the words HOT, COLD, and LUKEWARM, using common temperature words like hot, hotter, hottest, warm, cool, cold, coldest. Be sure the students understand that the same substance (water in this case) can have different temperatures, and yet look exactly the same.

   Words like hot and cold are used in a relative fashion. In the summer, for example, a day with a temperature of 15°C (60°F) would be considered quite cold. In the winter, 15°C (60°F) would mean a very warm day. A warm swimming pool and a cool bathtub might have exactly the same temperature water. Using a standard scale, such as temperature in °C or °F, makes comparisons much easier.

2. If you have not already done so, use Activity Sheets 1-1C or 1-1F to make a large thermometer. Move the construction paper up and down, asking the students to say what might be happening to the temperature being measured.

3. You will need to make enough copies of Activity Sheets 1-3A and 1-3B for everyone in the class. If you do not plan to do the *Advanced Investigation* (Step 10), cover up the bottom of the Activity Sheet 1-3B with a piece of white paper before you start copying. You may also want to cover up either the Fahrenheit or Celsius thermometer as well. If your class will be doing the *Advanced Investigation*, have copies of Activity Sheet 1-3C available as well.

4. Remind the students that procedure is important. Use **PLAYING WITH SCIENCE: Temperature** to demonstrate what happens to the temperature if the thermistor is removed from the bowl before the temperature is recorded. Be sure they realize that they are to put the bowls in order before using the thermistor to check their results. Caution them to just quickly dip in the end of their fingers since the hot water may be too warm to plunge in their whole hand.

5. Divide the entire class into groups, each of which puts its own set of bowls in order. It will make discussion much easier if the same symbol is placed on the same bowl for every group. An easy to use set-up for the bowls might be:

Circle:	ice water (without any ice in it)
Half moon:	1/4 hot water, 3/4 cold water
Diamond:	1/2 hot water, 1/2 cold water
Rectangle:	3/4 hot water, 1/4 cold water
Triangle:	hot water

6. Have each group fill in Steps 1 and 2 on Activity Sheet 1-3A. They should also do Step 3, filling in the chart as they go.

7. Use **PLAYING WITH SCIENCE: Temperature** and select DO AN EXPERIMENT from the Main Menu. Set the Set-Up options as follows:

Range:	MAX	50°C	(130°F)
	MIN	0°C	(32°F)
Type of display:	Thermometer		
Time:	15 minutes		
Number of thermistors:	1		

One-Computer Classroom: Bring the class together again, and use a large monitor so that everyone can see the results of measuring the temperature of the water with the thermistors. Point out that as the temperature of the water goes up, the bar on the thermometer goes up. Everyone should record the temperatures of the bowls on their copies of Activity Sheets 1-3B. Let each student label the thermometer at the bottom of Activity Sheet 1-3B independently. Have older students answer the questions on Activity Sheet 1-3A.

Multi-Computer Classroom: Each group should complete Activity Sheet 1-3A and 1-3B individually. Afterwards, the class should be brought together again for guided discussion, and the large monitor used to discuss the effects of changing temperature on the bar of a thermometer.

8. Post-experiment discussion should follow the guidelines on the Activity Sheets. Give students time to think of their own answers to the questions before you present the 'right' ones. All students should answer Questions 6 and 7 on Activity Sheet 1-3A. Use these answers to start the discussion. Point out that the thermistors are used to double check results here.

9. Have students discuss why the hot water cooled off and the hot water warmed up. Ask questions such as: Where did the heat go? What could we do to get it back.

   The concept of room temperature is important in later experiments. This is a good time to emphasize it. Students should realize that the starting temperature of the thermistors will affect their measurements of room temperature if they don't delay a bit.

10. *Advanced Investigation*: Have the class wait 20 minutes, and then repeat the experiment. These results and a discussion of their observations are to be recorded in the spaces provided on Activity Sheets 1-3A, 1-3B,and 1-3C.

Getting the idea:

Be sure students understand that it is easy to distinguish the hottest and coldest bowls by hand because we are fairly sensitive to extremes in temperature. The middle bowls will be much harder to put in order, and it might be possible only with thermometers or the thermistors if the hot water is not very hot.

As time passes, the water that is colder than room temperature will absorb heat from the air and gradually warm up. The hot water will gradually lose heat to the air in an attempt to heat up the surrounding space, and thus cool off. After 20 minutes, the bowls should still have different temperatures, and the order will still be the same, but it will be harder to tell without the use of a tool such as the thermistors. The longer you wait, the closer in temperature the five bowls will be to each other and to room temperature. They will also be harder to tell apart. Eventually they will all be at room temperature.

In your discussion, try to use the words RADIATED and CONDUCTED. While these are not required vocabulary yet, students should begin to appreciate the difference. Just saying that heat is radiated away from the warm water into the room air, and conducted by the contact of cold water with the relatively warmer air into the cold water will make it easier to introduce these terms later.

Expanding the idea:

Have students design an experiment to monitor the temperature of bowls of hot and cold water sitting in a room over an extended period.

What happens to a cup of hot coffee when it sits in a room? What might be done to keep it warm? What happens to cold cans of soda if they sit in a room for a while? People are warmer than room air. Will they cool off if they sit in a room for a while? Why or why not? Can your students design an experiment to demonstrate their answers?

Activity Sheet 1-3A
Playing with Hot and Cold!

Question: What do we mean by hot, cold, and lukewarm?

Gathering the data:

Step 1) Put your hand in each bowl, one at a time. Which holds the warmest water? Which is the coldest? Which ones are in the middle?

_____

_____

Step 2) Put the bowls in order, with the hottest on the left and the coldest on the right. Is it hard to decide on the best order for the other three?

_____

_____

Step 3) Record the labels on bowls by drawing the symbols on the bowls on the Activity Sheet 1-3B. Be sure they are in the right order.

Step 4) Use **PLAYING WITH SCIENCE: Temperature** and select DO AN EXPERIMENT from the Main Menu. Set the Set-Up options as follows:

Range:	MAX	50°C	(130°F)
	MIN	0°C	(32°F)
Type of display:	Thermometer		
Time:	15 minutes		
Number of thermistors:	1		

Step 5) Select EXPERIMENT and when the EXPERIMENT screen appears, press RETURN again to start taking data.

Step 6) One at a time, place the thermistor in each of the bowls of water. Be sure to leave the thermistor in the bowl when you read the temperature. What happens if you take it out? _____

_____

_____

Record the temperatures over each bowl on Activity Sheet 1-3B. Did you get the order right? _____

Making observations:

Step 7) Use the large thermometer on the Activity Sheet and label the temperatures of the bowls. As the temperature increased, what happened to the height of the bar in the thermometer?

_____

What happened to the the bar when the temperature went down?

_____

_____

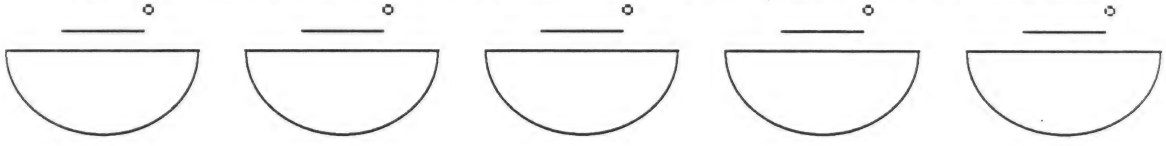
_____

Sunburst Communications © 1988

Activity Sheet 1-3B
What do we mean by hot and cold and lukewarm?

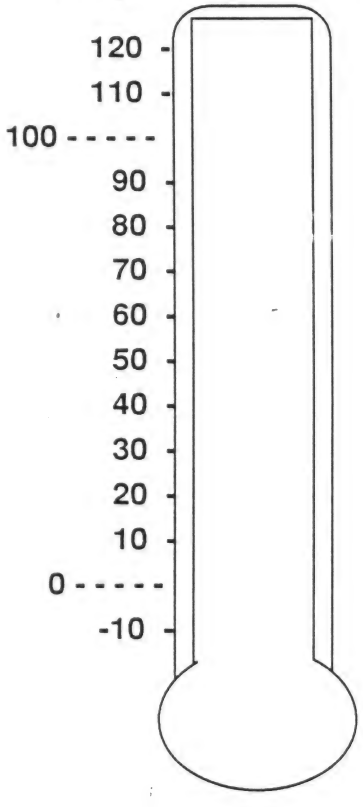
Put the bowls filled with water in order from HOTTEST to COLDEST. Copy the order or the labels on the bowls below. Write the water temperatures above the bowls. Then match the symbols to their temperatures on the thermometers below.

Temperatures after the water has been placed in the bowls

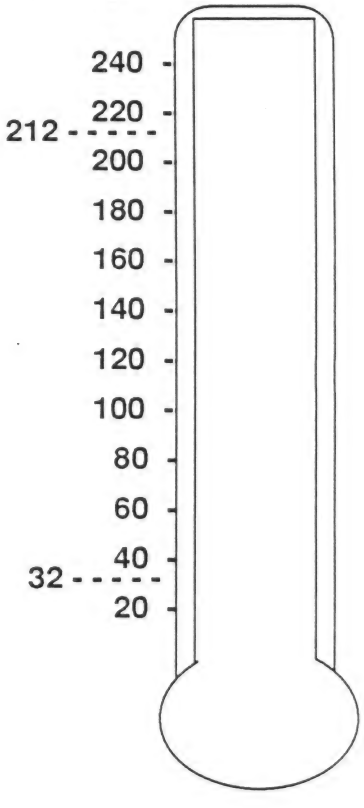


Hottest *Coldest*

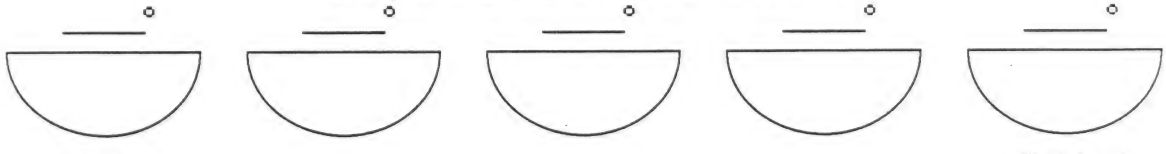
Temperature °C



Temperature °F



Temperatures after 20 minutes



Hottest *Coldest*

Sunburst Communications © 1988

Classroom Lesson Plan 1-4
Playing with Hot and Cold!

Question 1-4: What is the best source of heat?

Grade level: K-3

Equipment needed:

- A variety of different sources of heat. Light bulbs of different wattages, a sunny window, a candle, and hands are all good examples.
- **PLAYING WITH SCIENCE: Temperature** with the white thermistor and the extension cable.
- Copies of Activity Sheet 1-4 for every student.

Concepts:

- Sources of heat are all around us, some easy to find, some less obvious.
- Different sources of heat produce different amounts of heat.

Objectives:

The students will be able to:
- List at least five common sources of heat.

General description of the experiment:

Different sources of heat are listed and compared. By holding both hands and thermistors close to the different sources, students discover that the amount of heat emitted by different sources can be quite different.

Classroom lesson:

1. Start off this activity by having students make lists of all the heat sources they can think of. Have them identify each source as man-made or natural. Older students should also indicate whether the sources produce heat and light or just heat. Copy this information on the blackboard before doing Step 2.

2. Ask students to rate each heat source. Which one puts out the most heat? Which one the least? How do they know? Can they think of an experiment to try and decide which one is the best heat source?

3. Discuss the sun as a heat source. Be sure students realize that since the sun is so far away, it is very difficult to compare it to heat sources right here in the classroom.

4. Set up the light bulbs by screwing them into lamp stands with the shades removed. Light the candle. If you have access to florescent bulbs, plug them in as well. The classroom heating system is also worth investigating. Radiators and hot air vents can be tested by using the **PLAYING WITH SCIENCE: Temperature** extension cable.

5. Use **PLAYING WITH SCIENCE: Temperature**, and select DO AN EXPERIMENT from the Main Menu. Set the Set-Up options as follows:

Range:	Ignore this option
Type of display:	Digital
Time:	15 minutes
Number of thermistors:	1

6. Select EXPERIMENT and press RETURN. Press RETURN again to start taking temperatures. Now hold the thermistor about 2.5 cm (1 inch) from the heat source and count to 20. Be sure not to put the thermistor in or above the flame of the candle, or in contact with the light bulbs. Record the temperature and the type of heat source on the chart found in Activity Sheet 1-4.

7. One source of heat that students may not have thought of is hand friction. To explore this source, have students hold a thermistor between their hands and rub them together quickly. How much heat were they able to generate?

8. End this activity by having students rate the heat sources. A discussion of commercially useful sources of heat, such as coal, nuclear energy, and oil will also be valuable, if students are old enough to appreciate them.

Getting the idea:

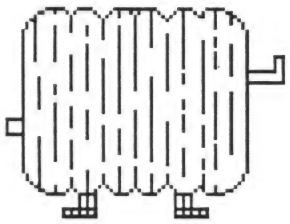
Making lists is an important component of science, and this activity is really just such an exercise. At the simplest level, the students will end up appreciating just how many different sources of heat there are. At more advanced levels, this activity can be a springboard into discussions on heat generation and measurement.

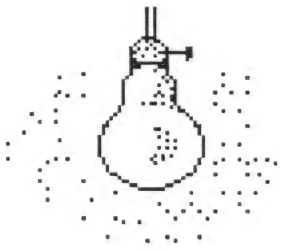
Expanding the idea:

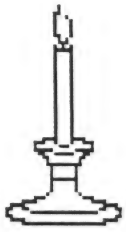
Have students look up different Energy Sources, Units of Measurement of Energy, Heat Energy, or Solar Energy. Have students find out what the source of heat is in their homes. If they are using oil heat, they can also find out how the oil gets to their homes in the first place. If their home is heated by a wood stove, discuss the economics of wood as an energy source. Electric heat is a little different, but worth discussing as an alternative to a direct energy source.

Activity Sheet 1-4
Playing with Hot and Cold!

Question: What is the best source of heat?







Gathering the data:

Step 1) How many different sources of heat can you think of?

Source	Man-made (Yes or No)	Natural (Yes or No)	Temperature 1 inch from source

Making observations:

Step 2) Which is the best source of heat? _____
Which is the worse source of heat? _____

Thinking about the results:

Step 3) Is there a difference between the natural and man-made sources of heat? _____
_____

Step 4) What is the major source of heat in your house? _____
What are some other sources of heat in your house?
_____
_____
_____
_____

Sunburst Communications © 1988

Classroom Lesson Plan 1-5
Playing with Hot and Cold!

Question 1-5: Can you guess what someone is doing by looking at a graph?

Grade level: K-5

Equipment needed:

- Each group of students will need three bowls, one filled with hot water, one filled with room temperature water, and one filled with cold water.
- Large cardboard boxes, one for each group of students.
- **PLAYING WITH SCIENCE: Temperature** with the white thermistor.
- Copies of Activity Sheet 1-5 for your entire class.

Concepts:

- Graphs are records of events, and can be used to generate hypotheses on what might have happened.
- Hot things make the temperature go up, cold things make the temperature go down.

Objectives:

The students will be able to:

- Recognize that higher temperatures are due to hotter objects, lower temperatures to cooler ones.
- Quickly interpret a bar graph, and make an educated guess as to how a specific temperature might have been achieved.

General description of the experiment:

This experiment is really more of a game. Students take turns producing bars on a bar graph, and then ask other students to guess what they did to make the graph. Young students start one bar at a time, older students can switch to line graph mode, print out the graph and have the other student match their work that way. By reinforcing the distinction between the TEMPERATURE of an object and the THERMOMETER used to measure the temperature, students develop a better understanding of this tricky concept. They also have an opportunity to practice their graph reading skills.

Classroom lesson:

1. Start by emphasizing the difference between THERMOMETER (something we measure Temperature with) and TEMPERATURE (the thing we actually measure).

2. This experiment is best done in a game spirit, with students developing the problems that other students will have to solve. If you want to divide the class up into teams and set up a score card, go ahead. Adding a competitive element here will extend student interest and encourage them to pay close attention to the graphs being drawn.

3. Use **PLAYING WITH SCIENCE: Temperature** and select DO AN EXPERIMENT from the Main Menu. Set the Set-Up options as follows:

Range:	MAX	100°C	(212°F)
	MIN	0°C	(32°F)
Type of display:	Bar		
Time:	15 minutes		
Number of thermistors:	1		

   One-Computer Classroom: Bring the class together and use a large monitor so that everyone can see the results. Put a large piece of cardboard or other screening between two students. The students should not be able to see each other, but the class should be able to see both students. Give each student three bowls of water, one hot, one cold, and one lukewarm. Everyone should keep their own record of the activity on a copy of Activity Sheet 1-5.

   Multi-Computer Classroom: Set up each group with three bowls of water, one hot, one cold, one lukewarm. Let the student who goes first work inside of a large box, or behind a cardboard screen. The other students in the group should not be able to see what the first student is doing. Each person in each group should complete Activity Sheet 1-5 individually.

4. Have students start taking data by pressing RETURN. The first bar on the graph is made by having a student, without telling anyone, stick the thermistor into one of the bowls, wait until the temperature stabilizes, and then press RETURN again. Now it is up to the other students to decide which bowl the first student used. Beginning students can be given the opportunity to try all three bowls before making their decision. As they become more experienced, have them attempt to always get the bowls right on the first try.

5. After everyone in each group has had a chance to produce an original bar and to try and match someone else's bar graph, begin a quick discussion of their results. Emphasize that higher temperatures imply hotter things, lower temperatures cooler things.

Activity Sheet 1-5
Playing with Hot and Cold!

Question: Can you guess what someone is doing by looking at a graph?

Gathering the data:

Step 1) Before doing this experiment, fill three bowls with water, one hot, one cold, and one lukewarm. Put the bowls behind a screen or in a box so that access is easy, but only one person can see in.

Step 2) Use **PLAYING WITH SCIENCE: Temperature** and select DO AN EXPERIMENT from the Main Menu. Set the Set-Up options as follows:

Range:	MAX	80°C (150°F)
	MIN	0°C (32°F)
Type of display:	Bar	
Time:	15 minutes	
Number of thermistors:	1	

Step 3) Select EXPERIMENT and when the EXPERIMENT screen appears, press RETURN again to start taking data.

Step 4) Let one of the group go behind the screen. At random, they should put the thermistor in one of the bowls and press RETURN to start taking data. When the temperature has stopped changing, they should press RETURN once more to stop taking data.

Step 5) Now can you guess (from the graph alone) which bowl the thermistor was in? Put the thermistor in the bowl you think is correct. Press RETURN to start taking data again. Were you right? Try different bowls if necessary, until you match the first bar. Press RETURN to stop. Record which bowl was the correct one, and the number of tries you needed to get a match on the chart below.

Step 6) Repeat Step 4 several times, letting everyone in the group have a chance to make the original puzzle bar and to try and match someone else's bar. Record all of the tries in the chart.

Sunburst Communications © 1988

Thinking about the results:

Step 7) How can you tell if the thermistor is in the bowl filled with hot water?

How can you tell if the thermistor is in the bowl filled with cold water?

How can you tell if the thermistor is in the bowl filled with lukewarm water?

ORIGINAL MEASUREMENT (Hot, cold, or lukewarm)	MATCHING MEASUREMENT (Hot, cold, or lukewarm)	# of tries required

Sunburst Communications © 1988

Activity Sheet 1-5A
Playing with Hot and Cold!

Question: Can you guess what someone is doing by looking at a graph?

Gathering the data:

Step 1) Before doing this experiment, get three bowls, one filled with hot tap water, one with cold water, and one with lukewarm water. Put the bowls behind a screen or in a large box so that access to the bowls is easy, but only one person can see in.

Step 2) Use **PLAYING WITH SCIENCE: Temperature** and select DO AN EXPERIMENT from the Main Menu. Set the Set-Up options as follows:

Range:	MAX	50°C (130°F)
	MIN	0°C (32°F)
Type of display:	Line	
Time:	1 minute	
Number of thermistors:	1	

Step 3) Select EXPERIMENT and when the EXPERIMENT screen appears, press RETURN again to start taking data.

Step 4) Choose one member of your group to design a puzzle for everyone else, using the three bowls of water and the one thermistor. They should place the thermistor in one bowl and count to 20. Then they should switch bowls, and again count to 20. There should be enough time to do this once more. When the minute is over, the computer will automatically stop taking data. At that point they should switch to ANALYZE DATA and print out a copy of the entire screen.

Step 5) Use the *Other* option to go back to EXPERIMENT. Have every other member of the group try to duplicate the graph, as shown in the printout by moving the thermistor from bowl to bowl. Could they do it?

Step 6) Repeat Steps 4 and 5 until everyone in your group has had a chance to design a puzzle for everyone else.

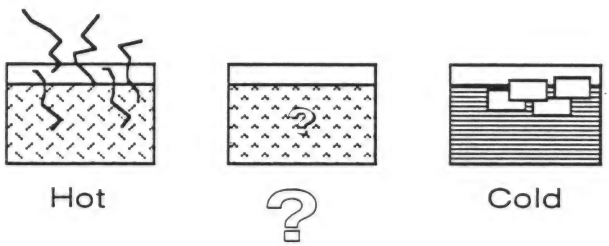
Step 7) If time permits, set up puzzle graphs that are longer, say 5 minutes or so. These will be much harder to duplicate, so keep them simple at first by leaving the thermistor in the bowl for at least a count of 30. The faster you move the thermistor, or the more different bowls you set-up, the harder the resulting puzzle will be to solve.

Sunburst Communications © 1988

Classroom Lesson Plan 2-1
Learning about your body

Question 2-1: Can water be hot and cold at the same time?

Grade level: K-7



Equipment needed:

- Sets of three bowls, one for each group. One bowl should contain hot tap water, another ice cold water (without ice cubes), and a third lukewarm water.
- *Advanced investigation*: **Playing with Science: Temperature** with all three thermistors.
- For very young students, have copies of Activity Sheet 2-1A on hand. If you teach older students, you will want to use Activity Sheet 2-1B instead. Use Activity Sheet 2-1C only if there is sufficient time.

Concepts:

- Our senses can be easily deceived.
- It is much harder to deceive an instrument, like a thermometer or a computerized thermistor.

Objectives:

The students will be able to:
- Recognize that their senses can be fooled.
- Recognize the difference between hot, cold, and lukewarm water when displayed on a line graph.
- Be able to interpret simple line graphs.

General description of the experiment:

Students explore a very old illusion, based on sensory adaptation. After holding one hand in hot water and the other in cold water, both hands are immersed in lukewarm water. To the 'cold' hand, the lukewarm water feels warm. To the 'hot' hand, the lukewarm water feels cool. Of course, the water is the same temperature, it is the student's perception of temperature that has been fooled.

Classroom lesson:

1. Before doing this experiment, spray some scented air freshener in the room about 20 minutes before recess. Have everyone smell it just after it is sprayed, and write down a quick description of what they smelled. Ask everyone to record their observations again just before recess. Be sure to shut the doors and windows while the students are at recess. Have them do a sniff test again when everyone comes back into the room. Have them discuss what changed during recess to explain the difference in odor. Hold off explaining the real reason why they noticed a difference until after the rest of the experiment has been performed.

2. Depending on the ages of your students, have them come one at a time to the front of the room to try the experiment described on Activity Sheet 2-1A, or have several groups working at once.

3. Every student should get a chance to try the experiment. Write down each student's name, and their perception of the temperature of the lukewarm water on the blackboard. Be sure to distinguish between the hand in hot water and the one in the cold water. Use standard school thermometers to measure the actual temperatures of the bowls, or you can use **PLAYING WITH SCIENCE: Temperature**.

4. With very young students, this will be sufficient information, and you should go immediately to a discussion based on the material found in **Getting the idea**. With older students, continue on with Step 5.

5. Use **PLAYING WITH SCIENCE: Temperature** and select DO AN EXPERIMENT from the Main Menu. Set the Set-Up options as follows:

Range:	MAX	50°C (130°F)
	MIN	0°C (32°F)
Type of display:	Line	
Time:	5 minutes	
Number of thermistors:	3	

6. Attach the computer to a large monitor, or divide the class into several smaller groups. Place the white thermistor in the bowl containing hot water, the blue thermistor in the bowl containing lukewarm water, and the green thermistor in the bowl containing cold water. Let the computer(s) record data for one minute.

7. Now, have students quickly plunge the green and white thermistors into the bowl of lukewarm water. Depending on the maturity of the students, have them record their results by filling in Activity Sheet 2-1B and then skip to **Getting the idea**. Very sophisticated students can continue working by following the directions on the Activity Sheet 2-1C. There is no need to save the data since the experiment described on Activity Sheet 2-1C is independent of the previous experiment.

Getting the idea:

The hand that was in the cold water feels the medium temperature as hot; the hand that was in the hot water feels the medium temperature as cold. What your students have experienced is *sensory adaptation*. This is what happens when any of your senses is exposed to the same strong sensation for a while. Your sensory receptors get used to the stimulation, and stop reacting after a time.

There are many examples of sensory adaptation in everyday life. For example, loud noises seem less bothersome after you listen for a while. Quiet voices are hard to hear after a music concert, but they become easier to understand after your senses adapt. You also notice the same effect when you first enter a house where someone has been baking. The smell is very strong when you first come in, but after a few minutes, it becomes much less noticeable. It is only when sensations change (a different smell, a louder noise, a colder room) that you become aware of them again.

If you use **PLAYING WITH SCIENCE: Temperature**, the resulting graph will show three distinct lines. The one near the top of the scale corresponds to the hot water, the one near the bottom is the cooler water. The lukewarm water's line should be in the middle.

Depending on the ages of your students, discuss this resultant graph with them. Younger students should simply recognize that the lower the temperature, the lower down the graph the line will be. For older students, point out that the lines are not completely flat. Even as you watch, the hot water is losing heat to the air, (the temperature goes down), and the cold water gains heat (absorbs heat) from the air (the temperature goes up).

Expanding the idea:

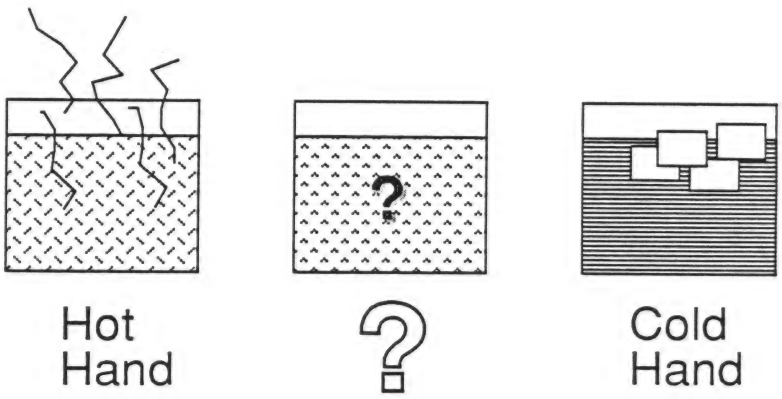
Have students describe other examples of sensory adaptation. Can they think of other experiments to demonstrate this principle? For example, perfume can be used to demonstrate the effect of sensory adaptation on our sense of smell, and a loud radio to show the effect on our ears.

The experiment described on Activity Sheet 2-1B is an excellent, yet simple way to get students used to using a computerized thermistor to double check temperatures. It also serves as a good introduction to simple graphing. If you use it for this purpose, ask questions such as: "What would happen to the locations of the lines on the graphs if the hot water was hotter at the beginning. If the cold water started cooler?" The experiment on Activity Sheet 2-1C continues exploring how thermistors react to hot and cold water.

Does the temperature of the lukewarm water affect your perception of its temperature? How could students design an experiment to test their answers?

Activity Sheet 2-1A
Learning about your body

Question: Can water be hot and cold at the same time?



What does it feel like?
(warm or cool)

_____

What does the
thermometer say?

_____

What does it feel like?
(warm or cool)

_____

What does the
thermometer say?

_____

Can water FEEL hot and cold at the same time? _____

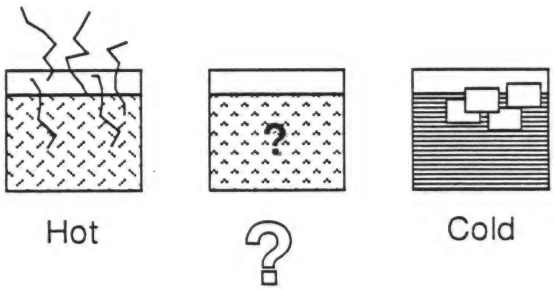
Is it REALLY hot and cold? _____

What fooled your hand? _____

Sunburst Communications © 1988

Activity Sheet 2-1B
Learning about your body

Question: Can water be hot and cold at the same time?



Gathering the data:

Step 1) Place one hand in the hot water, and the other in the cold water. Wait a few minutes.
Which hand feels hot? _____
Which hand feels cold? _____

Step 2) Now place both hands in the lukewarm water. What temperature does the water appear to be? Is it the same for both hands?

_____
_____
_____

Step 3) This effect is called *sensory adaptation*. After you discuss this concept in class, define it below in your own words.

_____
_____
_____

Step 4) Use **PLAYING WITH SCIENCE: Temperature** and select DO AN EXPERIMENT from the Main Menu. Set the Set-Up options as follows:

Range:	MAX	50°C (130°F)
	MIN	0°C (32°F)
Type of display:	Line	
Time:	5 minutes	
Number of thermistors:	3	

Step 5) Select EXPERIMENT.

Step 6) Put the white thermistor in the bowl containing hot water, the blue thermistor in the bowl containing lukewarm water, and the green thermistor in the cold water.

Step 7) Press RETURN to start recording data. Wait 1 minute for the temperatures to stop changing.

Sunburst Communications © 1988

Step 8) Now, in one motion, place the white and green thermistors in the bowl of lukewarm water with the blue thermistor. Wait 4 minutes and then press RETURN to stop collecting data.

Step 9) Switch to ANALYZE DATA. Use the *Print Screen* option to make a copy of the screen and attach it to this sheet. If your computer is not attached to a printer, sketch the graph in the space below. Use the graph to answer the following questions:

Can you tell which lines correspond to which thermistor?

_____

How do you know?

_____
_____
_____

Step 10) Label the lines on the graph clearly.

What happened to the temperature measured by the white thermistor when it was plunged into the lukewarm water?

_____
_____
_____

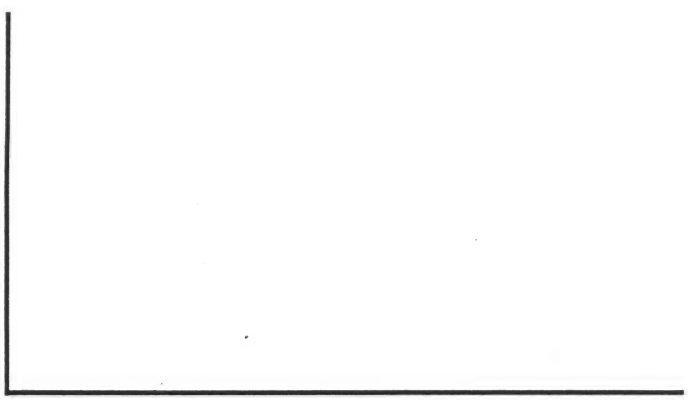
What happened to the temperature measured by the green thermistor when it was plunged into the lukewarm water?

_____
_____
_____

Did the thermistors suffer sensory adaptation? How do you know?

_____
_____
_____

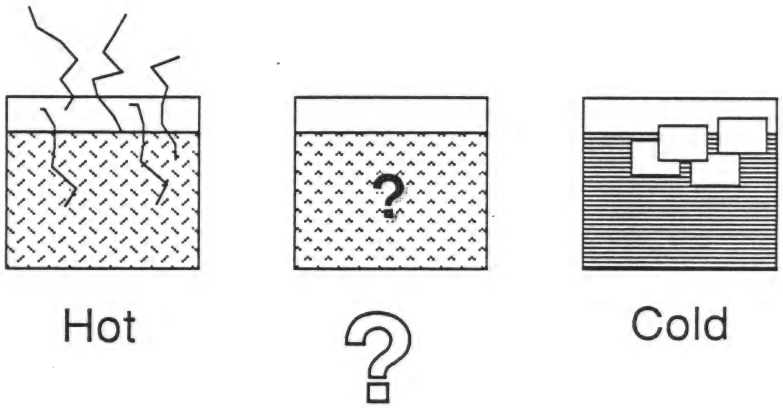
Attach the labeled graph or draw the graph below:



Sunburst Communications © 1988

Activity Sheet 2-1C
Learning about your body

Question: Can water be hot and cold at the same time?



Gathering the data:

Step 1) Use **PLAYING WITH SCIENCE: Temperature** and select DO AN EXPERIMENT from the Main Menu. Set the Set-Up options as follows:

Range:	MAX	50°C (130°F)
	MIN	0°C (32°F)
Type of display:	Line	
Time:	5 minutes	
Number of thermistors:	3	

Step 2) Select EXPERIMENT.

Step 3 Put the white thermistor in the bowl containing hot water, the blue one in the lukewarm water, and the green one in the cold water.

Step 4) Press RETURN to start collecting data. Wait a minute for the readings to stop changing.

Step 5) Remove the white thermistor from the hot water. What happens to the line on the graph? _____

_____

Why do you think it changed? _____

_____

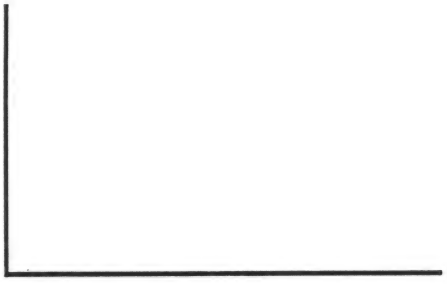
_____

Put the thermistor back in the bowl before continuing.

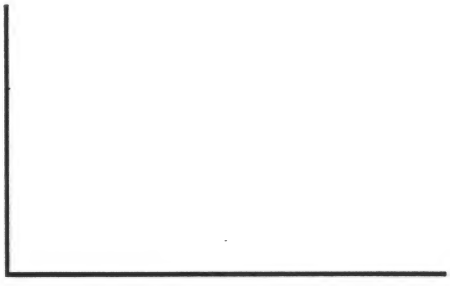
Sunburst Communications © 1988

Step 6) Before removing the thermistors from the other bowls, make a simple sketch of what you think will happen to the line on the graph that represents the temperature when each thermistor is removed:

the blue thermistor:



the green thermistor



Step 7) Now remove the thermistors. Are your sketches right? _____
If not, correct the sketches before continuing.

Thinking about the results:

Step 8) Why do you think the temperature of the green thermistor went up when you took it out of the cold water?

_____
_____
_____

Why do you think the temperature of the white thermistor went down when you took it out of the hot water?

_____
_____
_____

Sunburst Communications © 1988

Classroom Lesson Plan 2-2
Learning about your body

Question 2-2: How does your skin detect temperature?

Grade level: 1-5

Equipment needed:

Part One:
- Fine tipped felt pens of different colors. Each student or group of students will need two.
- A bowl of ice cold water with the ice removed, and a bowl of hot water for each group of students.
- One nail for each student or group of students.
- Copies of Activity Sheet 2-2 for every student.

Part Two:
- Two metal rods or large screwdrivers per student or student group.
- Bowl of warm water.

Concepts:

- Our bodies are covered with spots, called receptors, that our skin uses to determine temperature.
- Receptors are specialized: warm sensors respond to warmth, extreme sensors respond to cold.

Objectives:

The students will be able to:
- State that receptors on our skin help us determine temperature.
- Recognize that there are two kinds of receptors, warm sensors and extreme sensors.

General description of the experiment:

By using a nail dipped in cold water to find the extreme receptors and a nail dipped in hot water to find the hot receptors, students map out the locations of the receptors on their own bodies. Felt pens are used to mark the locations of the different receptors.

The second part of this activity demonstrates how easy it is to fool these sensors by exposing them to extremes of temperature. Students hold a freezing cold metal object and a warm metal object in the same hand, resulting in a 'hot' message being sent to the brain.

Classroom lesson:

1. Since students have already done Activity 2-1, they should be aware that our body is much less sensitive than we think it is. Begin this activity by asking students how they think their hands actually detect temperature.

2. Hand out two pens of different colors to each student or each group of students. Have each group get their own bowls of hot and cold water and one nail. They will also need one copy of Activity Sheet 2-2 per person.

3. Each student should draw a box about 2 cm square (1 inch square) on the back of their hands.

4. Have students start working with the cold water following the directions on Activity Sheet 2-2. They should continue working with the cold nail until they have isolated at least 10 cold receptors inside the square marked on their hands.

5. Now have students start working with the hot water, again following the directions on the Activity Sheet. By switching pen colors, they will be able to clearly see the difference between the hot and cold receptors.

6. Be sure that they try to cross spots, touching an extreme sensor with the nail when it is hot, for example.

7. When everyone has marked up their hands, stop the class and introduce the terms EXTREME SENSOR for the cold receptors and WARM SENSOR for the warm spots. After a brief discussion, your class is ready for the second part of Activity Sheet 2-2. If time is short, this part can easily be done at home. If you have plenty of time and sufficient freezer space, try it in class.

8. Discuss the results of these experiments, emphasizing the ease with which our bodies can be fooled.

Getting the idea:

Receptors detect temperatures hotter or colder than body temperature. The two different colors on the back of your students hands clearly demonstrates the existence of two different types of receptors. Extreme sensors react to cold temperatures, warm sensors to warmth. Stimulating both at the same time results in a hot message being sent to the brain.

Expanding the idea:

Students can explore other areas of their bodies the same ways. Chins, palms, forearms, and soles of feet are all good places to look for temperature receptors.

Activity Sheet 2-2
Learning about your body

Question: How does your skin detect temperature?

Gathering the data:

Part One:

Step 1) Draw a box about 2 cm square (1 inch square) on the back of your hand with one of the felt pens.

Step 2) Get a bowl filled with very cold water and put the nail in it until the nail is cold to the touch.

Step 3) Touch the tip of the nail to any spot inside the square. If you get a cold feeling, mark the spot with a dot from one of the pens. Keep touching the nail to your skin and marking the cold spots with dots from the same pen. If the nail begins to warm up, put it back into the cold water.

Step 4) When you've tested the entire square for cold, get a bowl full of hot water and set the nail in the hot water until it is hot to the touch.

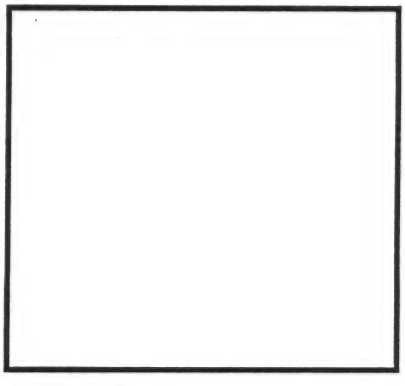
Step 5) Now repeat Step 3 with the hot nail. Mark the spots with a different color so that you can tell them apart.

Step 6) What happens if you touch a spot that reacted to the cold with the hot nail? Do you feel anything? _____

_____

_____

Step 7) When you have finished marking off all the spots in the square, copy the pattern into the square below.



Step 8) Were there more hot spots than cold spots? _____

_____

_____

Sunburst Communications © 1988

Part Two:

Step 1) Get two metal rods or two large screwdrivers. Put one in a freezer and the other in a bowl of warm water. Wait long enough for the rod in the freezer to get very cold (about 1 hour).

Step 2) Now remove the rods from the water and the freezer and hold them together in the palm of your hand. Be sure the two rods are touching. What do you feel? _____

_____

_____

_____

Step 3) Wait a minute. Do you feel anything different now?

_____

_____

_____

Step 4) The hot effect you felt is caused by overwhelming the two different kinds of receptors on your hand. What are the names of these two different types of receptors?

Cold: _____ Warm: _____

Sunburst Communications © 1988

Classroom Lesson Plan 2-3
Learning about your body

Question 2-3: Is the temperature of the air you breathe out warmer or colder than the air you breathe in?

Grade level: 1-5

Equipment needed:

- Fat plastic straws, like those used at McDonalds, enough for each person in the class to have their own.
- **PLAYING WITH SCIENCE: Temperature** with the white thermistor.
- Copies of Activity Sheet 2-3 for every student.

Advanced investigation:

- Copies of Activity Sheet 2-3A for every student.

Concepts:

- Air breathed out is warmer than air breathed in.
- Our bodies warm up the air we breathe in the process of using it.

Advanced Investigation only:

- The faster we breathe, the less chance our bodies have to warm up the air (and to get the oxygen out of it).
- Puffing and blowing appear to produce air with quite different temperatures, but the effect is caused by evaporation, while the temperature of the air is always the same.

Objectives:

The students will be able to:

- State that the air we breathe in is cooler than the air we breathe out.
- Recognize that there is a regularity to breathing and that temperature can be used to measure it.

General description of the experiment:

By breathing on the thermistor, students discover that the air that comes into their mouths is much cooler than the air that comes out. This shows up on the graph as a wavy line. By changing the scaling of the temperature axis, the variation in temperature is made more obvious. In the **Advanced investigation**, students explore the relationships between rate of respiration and temperature.

Classroom lesson:

1) Before doing the experiment, discuss personal health and safety with your students. Students should be reminded not to put the thermistors directly in their mouths. Give each person a straw and demonstrate how to place the thermistors in the bottom of the straws, using a little tape on the side to hold them there. Remind students to use their own straws.

2) Use **PLAYING WITH SCIENCE: Temperature** and select DO AN EXPERIMENT from the Main Menu. Set the Set-Up options as follows:

Range:	MAX	35°C	(95°F)
	MIN	25°C	(60°F)
Type of display:	Line		
Time:	10 minutes		
Number of thermistors:	1		

One-Computer Classroom: Use a large monitor so that the entire class can see the effect of breathing on the temperature of the air. Ask for volunteers but be sure to have them use different straws to prevent the spread of germs.

Multi-Computer Classroom: Divide students into groups two or three to a computer so that while one breathes into the straw, the others can watch the graphs. Everyone will want a turn, so be sure that they all use their own straws. After they have all had their turn to investigate the effect of their breath, gather the students around a central large monitor and repeat the experiment.

3) Have students answer Questions 4 and 5 on Activity Sheet 2-3 and discuss their answers. You may find that having some students actually do the breathing while the other students watch is the best way to get them to agree on the results. If the students find it difficult to answer the questions, switch to ANALYZE DATA and use the *Zoom* option for closer analysis.

4) Classroom discussion should center around the unusual shape of the graphs. Be sure that students realize that the temperature goes up when the air is breathed out. Ask students to suggest what the graph might look like if the air going in were colder, as on a cold winter day. What if the air was warmer?

5) Have students point out all the differences between the graphs that they can observe. Use the activity sheets to encourage the students to actually write down their ideas. The **Advanced investigation** encourages further discussion by asking students to artificially monitor their breathing.

Advanced investigation:

6) Students doing this part of the activity will be following the directions on Activity Sheet 2-3A, trying to quantify the results of the first part. Since the temperature differences will be small, they may need to use the *Graph* option in EXPERIMENT to change the MAX and MIN. To do this, have them press RETURN to stop taking measurements, highlight *Graph*, and press RETURN. They should then type in the new MAX, press RETURN, and type in the new MIN. The up arrow or the ESC key can be used to exit the window.

7) Air that is "puffed" out of the students' mouths will feel much warmer than air that is blown. The difference will appear to be at least several degrees. When the difference is actually measured using the thermistors, it will be more in the range of 1°. Be sure to emphasize that while the difference is still measurable (even thermistors can be fooled), it is much smaller than expected. Both our hands and the thermistors are fooled, since the air is actually the same temperature, only the rate of evaporation has been changed, generating the marked cooling effect of "blown" air.

Getting the idea:

The air we breathe in is at room temperature, but the human body is, of course, much warmer. When the air gets into our lungs, several interesting things happen. Some of the oxygen is taken out, and heat from our body is absorbed by the air. The longer the air is in our lungs and the deeper we breathe, the warmer it gets.

To see these differences requires a very sensitive thermometer. The thermistors accompanying **PLAYING WITH SCIENCE: Temperature** work very well, provided the Maximum and Minimum temperatures have been set quite close to each other and the measured temperature. A spread of only 1 or 2 degrees will give the best results.

When we puff air, it leaves our mouth slowly, and is as warm as our body made it. When we blow out air, it is actually the same temperature as the air we puff, but it feels much cooler. This is caused by evaporation of the water on the surface of the object that detects the temperature, whether the object is a hand, soup, or a thermistor. This is an example of the fallibility of instruments. The thermistor is fooled, just the way the sensory receptors on our hand are fooled. Classroom Lessons 5-1 and 5-2 look at evaporation and its effect on temperature in more detail.

Expanding the idea:

Have students design an experiment to measure rate of respiration. Discuss why breathing slowly makes you feel calmer if you've been running quickly or if you've been scared.

Ask students to decide how they think oral thermometers work. What would happen to the temperature they read if you open your mouth? Can they design an experiment to test their conclusion?

Activity Sheet 2-3
Learning about your body

Question: Is the temperature of the air you breathe out warmer or colder than the air you breathe in?

Gathering the data:

Step 1) Use **PLAYING WITH SCIENCE: Temperature** and select DO AN EXPERIMENT from the Main Menu. Set the Set-Up options as follows:

Range:	MAX	35°C	(95°F)
	MIN	25°C	(60°F)
Type of display:	Line		
Time:	10 minutes		
Number of thermistors:	1		

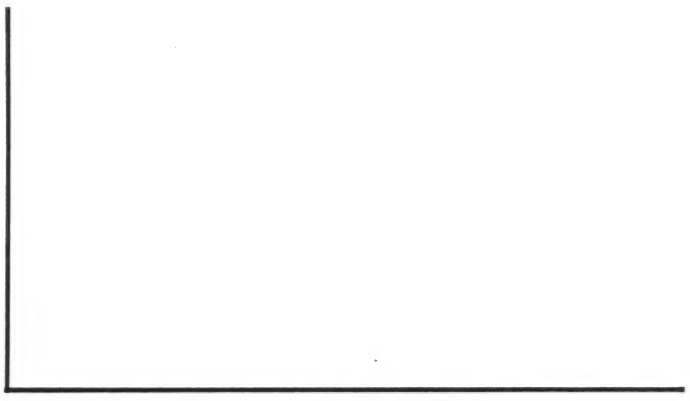
Step 2) Place the white thermistor inside the straw, about 1" from the bottom. Use tape to hold it in place if necessary.

Step 3) Select EXPERIMENT and press RETURN to start taking data.

Step 4) Breathe in and out through the other end of the straw. Press RETURN to stop. What happens to the graph? Is the temperature higher when you are breathing in or out? How can you tell?

_____
_____
_____
_____

Press RETURN again, and this time breathe in and out several times before pressing RETURN to stop taking data. Sketch the graph you see below and indicate with arrows and words which part of the graph shows the temperature when you breathe in, and which part shows the temperature when you breathe out.



Sunburst Communications © 1988

Step 5) What do you think the distance between the peaks of the graph represents? Try the following to find out.

Record the time showing on the timer right now. _____

Now press RETURN to start taking data again, and breathe slowly. Be sure to continue breathing for at least 5 complete in and out cycles. Press RETURN to stop. How much time is showing on the timer now?

_____

Find the time required to take 5 breaths by subtraction. How long did it take you to do the breathing? _____

Do you think you were breathing faster or slower than your friends?

_____

Now divide the time you required to breathe 5 times by 5. That will give you the time per breath. _____

Compare your time with some of your friends. Are the answers the same or different? What could you do to match the times of your friends? _____

_____

Step 6) Start taking data again, and try to breathe much faster for 5 cycles. Press RETURN to stop. Did the distance between the peaks appear to change? How? _____

_____

_____

Repeat the calculations above, and figure out the new time per breath. Were you as much faster as you though you were? Did breathing faster feel different? _____

_____

_____

Step 7) Repeat Step 6, breathing at a medium rate. What is your time per breath now? _____

Step 8) Save the data by selecting the *Save data* option. Give the file a name you can remember. Write the name down here for safe keeping.

_____

Step 9) Switch to ANALYZE DATA. Use the *Zoom* option to enlarge the picture and *See Data* to check on specific values. Can you answer question 6 any better now? _____

_____

_____

Step 10) What does the distance between the peaks represent?

_____

_____

Sunburst Communications © 1988

Activity Sheet 2-3A
Learning about your body

Advanced investigation

This activity explores some other effects on respiration that can be measured using temperature. Use the data saved earlier in Activity 2-3. If you had to turn off the computer, you can retrieve this data by selecting the *Disk* option and then selecting *Load Data*. Use the arrow keys and RETURN to select the name of the data file which you previously saved.

Step 1) Use the *Zoom* option to magnify the section of the data that was taken during Steps 5 to 10 in Activity 2-3. Use the *See Data* option to fill in the following:

Breathing rate:	Time of 1st peak	Time of 5th peak	Difference
Slowest rate	_____	_____	_____
Medium rate	_____	_____	_____
Fastest rate	_____	_____	_____

Breathing rate:	Temp of 1st peak	Temp of 5th peak	Average temp.
Slowest rate	_____	_____	_____
Medium rate	_____	_____	_____
Fastest rate	_____	_____	_____

What happens to the change in temperature of the air you breathe if you breathe faster? _____

_____

_____

What happens to the change in temperature of the air you breathe if you breathe slower? _____

_____

_____

Step 2) There are two different ways to let air out of your body. You can open your mouth wide and puff, or close your mouth almost completely and blow. Do you think the temperature of the air will be different?

_____

_____

Try puffing and blowing on your hand. Can you feel a difference in the temperature?

_____

_____

Sunburst Communications © 1988

Step 3) Go back to EXPERIMENT. Press RETURN to start taking data. Puff on the thermistor. Wait a few seconds for the thermistor to stop changing and then puff again. How warm is the breath that you puff?

_____

Now try blowing on the thermistor. Wait a few seconds and blow again. How warm is the breath that you blow?

_____

How do the measured temperatures compare?

_____
_____
_____

Does this agree with what you felt on your hand? Is the difference as dramatic as it felt to your hand? Can you suggest an explanation?

_____
_____
_____
_____

Do you think there should be a difference?

_____
_____
_____
_____

Is it possible that your body knows if you will be puffing or blowing and warms up the air differently? _____

If not, why does the air feel different? What other things have changed that might affect the temperature your hand feels?

_____
_____
_____
_____

Sunburst Communications © 1988

Classroom Lesson Plan 2-4
Learning about your body

Question 2-1: How are you different from your neighbor?

Grade level: 3-6

Equipment needed:

- Measuring tapes, rulers, and a bathroom scale.
- **PLAYING WITH SCIENCE: Temperature** with all three thermistors.
- Copies of Activity Sheet 2-4 for every student, plus a copy of the chart on the blackboard.

Concepts:

- There are wide variations among individuals, but they still exhibit similarity in body shape and size.
- The length of the limbs of the body are proportional to each other.
- The limb used the most (usually the right hand) develops the most.
- Hand temperatures, just like more obvious characteristics, differ from person to person.

Objectives:

The students will be able to:

- Measure parts of the body such as the arm, fingers, palms, and legs.
- Weigh (or mass) themselves.
- State evidence to show that while there is variation among individuals, they still share similar body shapes.

General description of the experiment:

Students are presented with a variety of measuring devices and asked to measure body characteristics, such as length of arm, hand temperature, and body weight. Averages are calculated on all characteristics, and these are used to predict the characteristics of the next student to enter the class.

Classroom lesson:

1. Start the discussion by having students list ways in which they are similar to their neighbors and ways in which they are different. After students have listed all of the common similarities, ask about hands? Are they the same size? What about height, weight, arm length? How would they go about finding out?

2. Have a volunteer stand in front of the class, and make the measurements described in Activity Sheet 2-4 on the volunteer. The class should watch carefully so that they will be able to repeat the procedures on one another.

3. Divide the class into groups, and assign each group a list of measurements to make. Have some start with height, others with weight, still others with lengths of upper arms, etc. By rotating students through the different measurements, you will be able to use less equipment.

4. Use **PLAYING WITH SCIENCE: Temperature** and select DO AN EXPERIMENT from the Main Menu. Set the Set-Up options as follows:

Range:	MAX	40°C	(100°F)
	MIN	25°C	(75°F)
Type of display:	Bar		
Number of thermistors:	2		

5. When it comes time to measure hand and underarm temperatures, have each student come up to one computer and press RETURN to start recording data. They should hold the white thermistor in their left hand, the blue thermistor in their right hand, and the green thermistor under their arm. Have them hold the thermistors until the temperature stabilizes. Press RETURN to record this measurement, and record the measured values on Activity Sheet 2-4.

6. As student groups finish making their measurements, have them record them on the blackboard.

7. You can use **PLAYING WITH SCIENCE: Temperature** to print out all the temperature measurements by switching to ANALYZE DATA and selecting *Print All*. The charts can be posted where all can see and discuss.

8. Have students calculate averages for each of the measurements. If you have a spreadsheet available, type in the numbers and let the computer do the math. If students are not able to calculate the averages, do it for them, and record the averages on the board for them to add to their charts.

9. Hand temperature will vary due to normal variations in circulation. Ask students if they ever notice that their hands feel warmer or colder than normal. To demonstrate the difference a little exercise can make, have every student jump up and down several times, and then measure their hand temperatures. Do they change? Up or down?

10. Students may notice that their right arm is slightly longer than their left arm. This can be related to heavier use. Since most people tend to use their right arms more than their left arms, there is a greater circulation of blood, and thus the arm receives more nourishment and can grow more.

11. Finish the activity by going back to the original list of differences and show how close we all actually are to the average values. Ask the class if this average is truly representative of humans of their age group. Point out that all of these measurements can be affected by heredity and diet. Older students might be shown photographs of people from other parts of the world and asked to list similarities and differences.

Getting the idea:

Being able to measure your body and know that bodies are basically similar in design and structure are very important to the understanding that we are all variations on the human design. Just as in any other pattern recognition exercise, the critical idea is to see that there is a basic pattern that we all fit into, with individual variations.

Normal variations that should be pointed out to students include the size of right vs left arms (due to heavier use and therefore increased circulation), hand temperature (due to mood, circulation, and exercise), and height (related to diet and heredity).

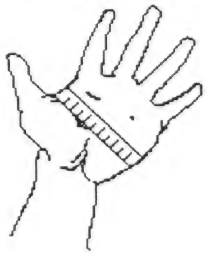
Expanding the idea:

Collections of pictures of people from around the world can be used to dramatically illustrate similarities and differences. Having students go into a different classroom with different age students will point up differences even more dramatically.

There are fairly inexpensive devices available that can be used to measure other normal body functions. For example, Hubbard Scientific (P.O. Box 104, Northbrook, IL 60062, 1-800-323-8368) has an excellent science catalog that lists, among other interesting tools, a grip tester, a limber gauge, and a breath control device. Stethoscopes are available both from Hubbard and from Edmund Scientific (101 East Gloucester Pike, Barrington, NJ 08007, 1-800-257-6173). If you have access to any of these, have students design experiments to test for similarities and differences.

Activity Sheet 2-4
Learning about your body

Question: How are you different from your neighbor?



Gathering the data:

Step 1) Using measuring tapes to measure lengths and widths, a bathroom scale to measure weight, and **PLAYING WITH SCIENCE: Temperature** to measure temperatures, fill in Chart 2-4.

Step 2) Add your measurements to the chart on the blackboard, and copy down the measurements from at least five of your classmates.

Making observations:

Step 3) Answer the following questions:

Which finger on your hand was the longest? _____
Which finger is the longest on average? _____

What is the average weight for the class? _____
Is your weight above or below average? _____

What is the ratio of your height to your weight? _____
What is the ratio of average height to average weight? _____

What is the average size of palm? _____
How different was your palm from average? _____
Is there a difference between right and left palms? _____

Which is longer, your right arm or your left arm? _____
Which is longer on the average, your classmates' right arms or their left arms? _____

Which hand is warmer, your right or your left? _____
What is the average hand temperature in the class? _____

What is your body temperature? _____
What is the average body temperature? _____

Which had more variation, (more difference), underarm temperature or hand temperature among your classmates? _____

Thinking about the results:

Step 4) Predict the size and measurements of the next new boy or girl to enter your class:

Height _____ Weight _____
Underarm temp. _____ Length of arm _____
Length of leg _____ Length of longest finger _____

Sunburst Communications © 1988

Chart 2-4

Body Part	Your measurements	Your classmates' measurements 1	2	3	4	5	Average
Fingers							
pinky							
ring							
middle							
index							
Thumb							
Palms							
right							
left							
Height							
Weight							
Right Arm							
whole							
lower							
upper							
Left Arm							
whole							
lower							
upper							
Leg							
whole							
lower							
upper							
Temperatures							
right hand							
left hand							
underarm							

Sunburst Communications © 1988

Classroom Lesson Plan 3-1
Why do things get warmer?

Question 3-1: Do different materials let the same amount of heat pass through?

Grade level: K-3

Equipment needed:

- Working table lamp with the shade removed.
- Standard light bulb, 100 watt if possible.
- Several large squares (at least 3" x 3") of different materials. Cardboard, glass, aluminum foil, and transparent plastic are good choices.
- Meter stick or tape measure fastened to the table at the base of the lamp.
- Copies of Activity Sheet 3-1 for every member of your class.
- **PLAYING WITH SCIENCE: Temperature** with the white and blue thermistors.

Concepts:

- Heat travels in the form of radiated energy from a hot object.
- Some materials block both heat and light radiation, while others block heat radiation but not light radiation. In this experiment, cardboard blocks both, and glass and plastic are better at blocking heat radiation than they are at blocking light radiation.

Objectives:

The student will be able to:

- Describe the different ways a hand feels when placed behind different materials, yet near a light bulb.
- Describe the qualitative effects of different materials on the amount of heat received.
- State the effects of glass, plastic, and cardboard on the heat radiated from a light bulb.

General description of the experiment:

Students explore the amount of heat energy radiated from a light source by first simply holding their hands near by. Then they block the light using squares made of cardboard, glass and transparent plastic. In all three cases, the heat is at least partially blocked, with the cardboard best at blocking both light and heat. In the case of glass and transparent plastic, the light is transmitted, even though most of the heat energy is stopped.

Classroom lesson:

1. Place a table lamp, with the shade removed, on a table. Screw in a standard 100 watt bulb, and plug in the lamp.

2. Put a meter stick on the table, one end against the base of the lamp, and the other end pointing directly away from the lamp. Put a piece of tape 10 cm. (4 inches) from the base of the lamp. If you have a large class, you can mark a circle with tape around the lamp. You may also wish to use several lamps to avoid crowding.

3. Start the discussion by turning on a lamp and holding your hand 10 cm from the light. Ask students what they think you should be feeling. Ask them where the heat comes from. How does the heat get to your hand? Does the size of the light bulb make a difference? Will the distance from the light bulb make a difference?

4. Hand out copies of Activity Sheet 3-1 to every student in the class.

5. Turn on the table lamps and turn off the room lights. Have students hold their hands in front of the lights, directly over the tape. Have them record their impressions on the first part of the chart on Activity Sheet 3-1.

6. Have the students gradually back away from the lights in a straight line, using small steps. After each step, they should stop and again record what they feel. Let them continue backing away until they can no longer be sure that they detect any heat from the light at all.

7. Start **PLAYING WITH SCIENCE: Temperature** and set the Set-Up options as follows:

Range:	MAX	40°C	(110°F)
	MIN	15°C	(60°F)
Type of display:	Bar		
Time:	Ignore this option		
Number of thermistors:	2		

One-Computer Classroom: Have all the students sit down where they can see the computer and the light bulb. Do the experiment as described below by yourself, and have every student record the results and their answers to the questions on their own copies of Activity Sheet 3-1.

Multi-Computer Classroom: Let each group do their own measurements of the heat emitted by the light bulb. Use the extension cord to allow the thermistors to reach to the lamp. Have students record their results and answer the questions independently.

8. This activity starts by having each group find the most desirable range to use. First, room temperature is measured, and is assumed to be the minimum temperature. To find the maximum, students hold the white thermistor 10 cm (4 inches) from the light bulb and count to 50. After using the *Graph* option to update these values, the experiment itself is begun.

9. Each group fastens the white thermistor with tape to one side of a cardboard square and the blue thermistor to the other side. Have them hold the square over the 10 cm mark, with the white thermistor facing the light bulb. Pressing RETURN once starts the data collection. They should count to 50, and press RETURN once more to stop gathering data. On the chart they should record the trial number, the temperatures measured on both sides of the square, the type of material used, and then let the thermistors return to room temperature.

10. This procedure should be repeated with each of the other squares. Remind your students to always have the white thermistor facing the light source, and the blue one turned away. They should continue to take measurements and fill in the chart until they have tried all the different types of materials available.

11. Have students switch to ANALYZE DATA and zoom in on the graph so that they can clearly see the changes in temperature. Have them answer the questions on Activity Sheet 3-1 to the best of their ability.

12. Questions 8 through 10 ask students to apply the idea that glass lets only some of the heat through but virtually all of the light. Discuss their answers after they have had an opportunity to decide for themselves what the correct answers might be.

13. Topics to discuss after the experiment is over include the difference between visible light and infrared radiation (heat). Ask students to list things that will block visible light and those that block infrared (heat). Be sure students understand that air is not necessary for either heat or light to radiate through. Since list building is a critical component of science, you may want students to work on their lists at home with their parents.

Getting the idea:

All students should understand that objects warmer than their surroundings radiate heat in an attempt to equalize the temperature. The greater the difference in temperature between the object and its surroundings, the easier it is for our hands or bodies to detect this radiation.

This kind of heat is more formally called radiant heat or infrared radiation. You cannot see radiant heat, and it does not require the presence of air in order to move from place to place. For example, the earth is warmed by the sun through radiant heat, but there is almost no air in space. Visible light is very similar to radiant heat, but has more energy. Ultraviolet light, the kind of light that gives you a tan, has even more energy than visible light, and can be very dangerous to skin and eyes.

All three kinds of "light" are part of the electromagnetic spectrum, and the term light is generic for both heat and visible light. In fact, we could say that visible light is just the kind of light we can see, while infrared light is the kind of light we feel. Ultraviolet light is dangerous because it contains so much energy. Since this is the type of light that causes sunburns, and infrared is the kind that makes us feel warm, it is easy to see why you can still get a sunburn on a cloudy day. The heat (infrared light) is stopped by the clouds, but the ultraviolet still gets through to burn our skin. We can also get sunburns in winter, even though the air is cold, for the same reasons.

Plants grow well in greenhouses not because they are warm (although that certainly helps) but because the visible light, particularly in the red part of the spectrum, is allowed to pass freely through the glass. Ultraviolet light, on the other hand, is effectively stopped by normal glass, and thus it is hard to get a sunburn in a greenhouse unless special glass is used that doesn't stop the ultraviolet rays.

Inexpensive glass squares can be obtained by removing the glass from picture frames, putting them back when the experiment is finished. Plastic squares can be made by building wire frames and then wrapping them in layers of clear plastic wrap.

Expanding the idea:

If you have a greenhouse in the classroom, you might want to have students design an experiment to monitor temperature inside and outside. Explain that the increased warmth will require that they think about getting rid of the heat, as well as just allowing it to pass through the glass.

The kind of plastic used will affect the amount of heat that passes through. Can your students design an experiment that would test different types of plastics?

Activity Sheet 3-1
Why do things get warmer?

Question: Do different materials let the same amount of heat pass through?

Setting up the experiment:

Step 1) Hold your hand 10 cm (4 inches) away from a light bulb. Does your hand feel warm? Hot? _____

Step 2) Now slowly back away from the light bulb, still holding your hand out. Fill in the following chart, recording when you feel a difference:

Distance (in steps)	Can you still feel the heat? (yes or no)
_____1 step ____	_____
_____2 steps____	_____
_____3 steps____	_____
_____4 steps____	_____
_____5 steps____	_____
_____6 steps____	_____
_____7 steps____	_____
_____8 steps____	_____

Step 3) Start **PLAYING WITH SCIENCE: Temperature**. Attach both the white and blue thermistors. Set the Set-Up options as follows:

Range:	MAX	40°C (110°F)
	MIN	15°C (60°F)
Type of display:	Bar	
Time:	15 minutes	
Number of thermistors:	2	

Step 3) Select EXPERIMENT and when the EXPERIMENT screen appears, press RETURN one more time to start taking data.

Gathering the data:

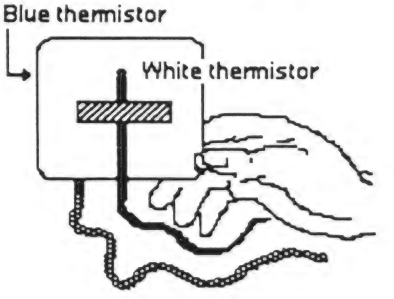
Step 4) The minimum temperature you will be measuring in this activity is room temperature. You can find out what it will be by leaving the thermistors alone until they stop changing temperature. Then press RETURN to stop taking temperatures. Record this information in the chart in Step 9.

Step 5) Now determine the highest temperature you will be measuring. This should be the temperature 10 cm (4 inches) from the light bulb. Without touching the ends of thermistors with your fingers, hold them up directly above the tape mark that indicates 10 cm (4 inches) and press RETURN to start taking the temperature. Count to 50 and press RETURN to stop taking temperatures. Put the thermistors down on the table to cool off, and record these measurements on the second line of the chart.

Sunburst Communications © 1988

Step 6) Room temperature is the minimum temperature you will be reading, and the temperature 10 cm (4 inches) from the light bulb is the maximum temperature. Adjust the scale on the **PLAYING WITH SCIENCE: Temperature** temperature axis to reflect this new information by doing the following. Select the *Graph* option. Notice that MAX is lit. Type in a value just a few degrees higher than the temperature near the light bulb. Press RETURN. The cursor will jump to MIN. Type in a value just a few degrees lower than room temperature. Press RETURN. Press ESC to return to the top menu.

Step 7) Get one of the squares of material. Record the type of material on the third line of the chart. Now tape the white thermistor to the front of the square and the blue thermistor to the back.



Hold the square in front of the light, 10 cm (4 inches) away. Press RETURN to start taking temperatures, count to 50, press RETURN to stop taking temperatures, and put the thermistors down. Now record these measurements on the chart and answer the questions about the first square.

Step 8) Repeat Step 7 with each square in turn. You should try the experiment with at least three different materials, among them glass, transparent plastic and cardboard. Use more materials if possible.

Step 9) Record the information in the chart below:

Room Temperature: _____
Temperature 10 cm from the light: _____

Type of material	Temperature on side near the light (white thermistor)	Temperature on side away from the light (blue thermistor)	Change in temperature
_____	_____	_____	_____
_____	_____	_____	_____
_____	_____	_____	_____
_____	_____	_____	_____

Sunburst Communications © 1988

Making observations:

Step 10) Fill in the blanks and answer the questions as best you can.

	Type of material	Does light go through?	Does heat go though?
First Square:	_____	_____	_____
Second Square:	_____	_____	_____
Third Square:	_____	_____	_____
Fourth Square:	_____	_____	_____
Fifth Square:	_____	_____	_____

Thinking about the results:

1. Which material lets the most light through? _____
2. Which material lets the most heat through? _____
3. Which material lets the least light through? _____
4. Which material lets the least heat through? _____
5. Does glass increase or decrease the amount of heat coming from the bulb to the blue thermistor? _____
6. Do you think heat and light are the same thing? Why or why not?
   _____
   _____
   _____
7. Based on the results of the first part of this experiment, what do you think happens to the intensity of radiation (the amount of heat received) as the distance from the source increases? _____
   _____
   _____
8. In the winter, where does the heat come from that warms your house?
   _____
   _____
   Which material would be better at keeping the heat inside your house, cardboard or glass? _____
   In the summer, where does the heat come from that makes your house too warm inside? _____
   _____
   _____
   Which material would be better at keeping the heat outside of your house, cardboard or glass? _____

Sunburst Communications © 1988

9. What do you think the advantages of having windows in homes are?

_____
_____
_____

What do you think the disadvantages are?

_____
_____
_____

10. If you lived in a cold climate, would you want to have a lot of windows in your house? _____

Why or why not? _____
_____
_____

If you lived in a warm climate, would you want to have a lot of windows in your house? _____

Why or why not? _____
_____
_____

If you lived in a hot climate, would you want to have a lot of windows in your house? _____

Why or why not? _____
_____
_____

Collect pictures of homes in different climates and see if they are built using what you have found out about heat and glass in this experiment.

Sunburst Communications © 1988

Classroom Lesson Plan 3-2
Why do things get warmer?

Question 3-2: How far from a fire can you sit and still feel warm?

Grade level: K-5

Equipment needed:

- Working table lamp with the shade removed.
- Standard light bulb, 100 watt if possible.
- Meter stick or tape measure fastened to the table at the base of the lamp.
- Copies of Activity Sheet 3-2 for every member of your class.
- **PLAYING WITH SCIENCE: Temperature** with the white thermistor.

Concepts:

- Heat travels in the form of radiated energy from a hot object.
- The amount of heat received depends inversely on the distance from the heat source. Most students should simply know that as distance increases, the amount of heat received decreases. Mathematically sophisticated students may be told that the relationship is an inverse square.

Objectives:

The students will be able to:

- Say that the amount of heat received from a source at any one point decreases as distance from the source increases.
- Qualitatively describe this relationship as an inverse one.
- Hypothesize that planets farther from the sun receive less heat, and thus are colder.

General description of the experiment:

Temperature is measured at certain distances from the source. As distance increases, the temperature will decrease, obeying the inverse square law. Students will note simply that a decrease occurs, and hypothesize how this affects the amount of heat received by different planets in the solar system.

Classroom lesson:

1. Place a table lamp, with the shade removed, on a table. Screw in a standard 100 watt bulb, and plug in the lamp.

2. Put a meter stick on the table, one end against the base of the lamp, and the other end pointing directly away from the lamp. Starting at the 5 cm mark from the base of the lamp, use pieces of tape to mark every 5 cm interval until you reach 50 cm. You should end up with 10 pieces of tape. If you have a large class, you can mark circles with tape around the lamp. You may also wish to use several lamps to avoid crowding.

3. Start the discussion by turning on a lamp and holding your hand close to the bulb. Ask students what they think you should be feeling. Ask them where the heat comes from. How does the heat get to your hand? Does the wattage of the light bulb make a difference? Will the distance from the light bulb make a difference?

4. Now gradually move your hand away from the bulb. Again ask students what they think you will feel. How far away do they think you should have to go to stop feeling the heat?

5. Hand out copies of Activity Sheet 3-2 to every student in the class.

6. Turn on the table lamps and turn off the room lights. Have students hold their hands in front of the lights, about 5 cm away from the bulb. Have them record their impressions on the first part of the chart on Activity Sheet 3-2.

7. Have the students gradually move their hands away from the lights in a straight line, using the tape marks as a guideline as to where to stop.

8. Start **PLAYING WITH SCIENCE: Temperature** and set the Set-Up options as follows.

Range:	MAX	40°C	(110°F)
	MIN	25°C	(80°F)
Type of display:	Bar		
Time:	Ignore this option		
Number of thermistors:	2		

One-Computer Classroom: Have all the students sit down where they can see the computer and the light bulb. Do the experiment as described below by yourself, and have every student record the results and their answers to the questions on their own copies of Activity Sheet 3-1.

Multi-Computer Classroom: Let each group do their own measurements of the heat emitted by the light bulb. Use the extension cord to allow the students plenty of room to move away from the heat source. Have students record their results and answer the questions independently.

9. Following the directions on Activity Sheet 3-2, have each group record room temperature. Continue to let the blue thermistor measure room temperature as a value for comparison to the temperature measured near the lamp. Then have each group fasten the white thermistor with tape to one side of a cardboard square. Now they should position the cardboard so that side with the thermistor faces the light bulb. Holding the card over the last tape mark (5 cm) they should press RETURN once to start collecting data. After counting to 50, they should press RETURN once more to stop gathering data, and let the thermistor return to room temperature. Meanwhile, they should record the temperature, the trial number, and the distance from the light bulb on the chart on Activity Sheet 3-2.

10. Students should repeat this procedure at each of the other positions of the tape. Altogether they should take ten different measurements, gradually getting farther and farther from the light bulb. Stop taking measurements when you reach the 50 cm mark.

11. Have students switch to ANALYZE DATA and zoom in on the graph so that they can clearly see the changes in temperature. Have them answer the questions on Activity Sheet 3-2 to the best of their ability.

12. Ask students to describe times that they have noticed that the amount of heat perceived depends on the distance from the object. What kind of objects were they? What shapes? Be sure students understand that air is not necessary for either heat or light to radiate through. This point can be reinforced by noting that the earth receives heat from the sun despite the distance involved and the lack of "air."

Getting the idea:

All students should understand that objects warmer than their surroundings radiate heat in an attempt to equalize the temperature. The greater the difference in temperature between the object and its surroundings, the easier it is for our hands or bodies to detect this radiation.

Distance from the heat source affects the amount of heat received, for a very simple reason. Imagine the surface of a balloon. As you blow it up, the distance from the center gets larger and larger, and the skin (the surface) of the balloon gets thinner and thinner. We can imagine the heat that comes from a light bulb as being like the skin of the balloon. As the distance from the bulb increases, the heat has to be spread over a greater distance, and thus is less effective at heating any particular point. Notice that the amount of heat given off has not changed, it is exactly the same no matter how far you are from the source. What has changed is the amount received at any one point on the surface. The larger the surface, the less heat per point.

Expanding the idea:

Have students try to measure the decrease in heat from the sun using the technique that worked with a light bulb. When they fail, you can discuss the huge amount of distance involved, and the very little difference our height makes. Discuss the temperature at the top of mountains. You are nearer the sun, why aren't you warmer? What other variables might it be necessary to take into account?

Flashlights prevent light from spreading out the way heat does from a point source by bending part of it back. The mirror at the back of the bulb does this bending. Do you think it might be possible to bend heat back the same way? What type of material would you use for a heat reflector? Can your students design an experiment to find out? (In Activity 4-7, students build a solar cooker, a device that is designed to focus heat to a point, rather than bend it back in straight lines. However, if you put a heat source right at the focal point, you would get exactly the same effect as a flashlight. When you do this activity, consider having your students place a candle at the focal point to produce a "flashheat!")

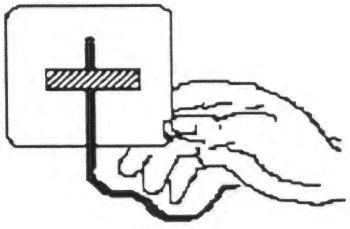
Activity Sheet 3-2
Why do things get warmer?

Question: How far from a fire can you sit and still feel warm?

Setting up the experiment:

Step 1) Hold your hand 10 cm (4 inches) away from a light bulb. Does your hand feel warm? Hot? _____

Step 2) Attach the white thermistor to a cardboard square so that you can handle it without touching the end. Put the blue thermistor on the floor or behind the computer, as far from the light as possible.



Step 3) Start **PLAYING WITH SCIENCE: Temperature**. Attach the white thermistor. Select DO AN EXPERIMENT from the Main Menu and set the Set-Up options as follows:

Range:	MAX	40°C	(110°F)
	MIN	25°C	(80°F)
Type of display:	Bar		
Time:	Ignore this option		
Number of thermistors:	2		

Step 4) Select EXPERIMENT and when the EXPERIMENT screen appears, press RETURN one more time to start taking data.

Gathering the data:

Step 5) Measure room temperature by leaving the thermistor alone until it stops changing temperature. Then press RETURN to stop monitoring the temperature. Record this information in the chart on the next page.

Step 6) Now let's start doing the experiment. The first measurement should be made when the thermistor is 5 cm from the light bulb. Hold the cardboard with the thermistor facing the light directly above the tape mark that indicates 5 cm (2.5 inches) and press RETURN to start monitoring the temperature. Count to 50, press RETURN to stop taking temperatures, and put the thermistor down. Now record these measurements on the second line of the chart.

Sunburst Communications © 1988

Step 7) Now slowly move away from the light bulb, still holding your hand out. Fill in the following chart, pressing RETURN once to start recording measurements and pressing RETURN again to stop.

Room Temperature _____

Bar Number	Distance (in steps)	Temperature
_____	5 cm	_____
_____	10 cm	_____
_____	15 cm	_____
_____	20 cm	_____
_____	25 cm	_____
_____	30 cm	_____
_____	35 cm	_____
_____	40 cm	_____
_____	45 cm	_____
_____	50 cm	_____

Making observations:

Step 8) Switch from EXPERIMENT to ANALYZE DATA. Change the *Type* to Line. Use the *Print* option to do a *Print Screen*. Attach the graph, with the following points labeled, to this worksheet.

- Room temperature
- Temperature at 5 cm
- Temperature at 10 cm
- Temperature at 20 cm
- Temperature at 40 cm

Step 9) Answer all the following questions as best as you can.

Does temperature increase or decrease as distance from the heat source increases? _____

Did the temperature decrease in a steady manner, or did it sometimes change quickly and sometimes change more slowly? _____

_____

_____

When did the temperature decrease the fastest? _____

_____

_____

When did the temperature change by the smallest amounts?

_____

_____

Is the line on the graph straight or curved? _____

Sunburst Communications © 1988

Thinking about the results:

Step 10) Planets receive their heat (and light) from the sun. Do you think distance will make a difference in the amount they receive?

_____
_____
_____

Pluto is much farther from the Sun than Mars is. Which planet would you expect to have the higher average surface temperature?

_____
_____

Both the Earth and Mars are relatively close to the Sun, but the Earth is slightly closer. Which of these planets do you think would have the higher average surface temperature? _____

_____

Step 11) The shape of a heat source and its immediate surroundings can make a big difference in the amount of heat received a certain distance away. For example, think about a standard home fireplace and a campfire. If they both contained the same amount of burning wood, we'd expect them to produce the same amount of heat. How do their shapes differ?

_____
_____
_____

What happens to the heat that hits the back of the fireplace? Where might it go? _____

_____
_____

Where do you think it would be warmer, 3 meters (10 ft) from a campfire or 3 meters (10 ft) from a fireplace? Why? _____

_____
_____

Step 12) Do you think it is possible to get so far from a heat source that no heat could reach you? Why or why not? _____

_____
_____
_____

Sunburst Communications © 1988

Classroom Lesson Plan 3-3
Why do things get warmer?

Question 3-3: What color clothing is the warmest?

Grade level: K-7

Equipment needed:

- **PLAYING WITH SCIENCE: Temperature** with all three thermistors.
- Small squares (about 10 cm or 4 inches on each side) of different colored material. Each group will need one square of white cloth, one square of black cloth, and one square of aluminum foil.
- Large squares of sturdy cardboard (45 cm or 18 inches square), one for each group.
- The 100 watt light bulb and table lamp used in Activities 3-1 and 3-2.
- Copies of Activity Sheet 3-3 for every student.

Concepts:

- When radiant energy is absorbed, temperature goes up.
- Dark colored objects absorb radiant heat faster than light colored objects.

Objectives:

The students will be able to:

- Discuss the meaning of radiant heat.
- Distinguish between objects that reflect radiant heat and those that absorb radiant heat.
- State that dark objects absorb heat faster than light colored objects do.

General description of the experiment:

Thermistors are placed under squares of different colored cloth and exposed to a heat source (a 100 watt light bulb). The temperature under the dark colored cloth increases the most, indicating that radiant heat is being absorbed by the cloth. The temperature under the light colored cloth also increases, but not as dramatically. The temperature under the aluminum foil does not increase at all, since the heat energy is being reflected by the material, not absorbed.

Classroom lesson:

1. Start by handing out copies of Activity Sheet 3-3, and by reviewing the results of Activities 3-1 and 3-2. In these, we discovered that heat travels in the form of radiated heat from hot objects, and that this heat decreases as distance from the source increases. We call heat of this type RADIANT HEAT. As a group, students should generate a definition and then record it on their own copies of Activity Sheet 3-3.

   This activity continues exploring radiant heat, this time by looking at differential absorption. Ask students what they think happens when radiant heat, from the sun perhaps, strikes a dark colored object. Does the inside get warm? Have they ever entered a dark car that has been sitting in the sun on a hot day? What was it like inside? Would a light colored car be as warm inside? How could we find out? What about objects that reflect light, will they get warm on the inside?

2. Start **PLAYING WITH SCIENCE: Temperature** and select DO AN EXPERIMENT from the Main Menu. Set the Set-Up options as follows:

Range:	MAX	50°C	(125°F)
	MIN	20°C	(70°F)
Type of display:	Line		
Time:	20 minutes		
Number of thermistors:	3		

   One-Computer Classroom: This is the preferred method if you are working with students who cannot yet read. Gather everyone around one computer, preferably hooked to a large monitor and follow the directions on Activity Sheet 3-3. Every student should fill in their own copies of the Activity Sheet if they have the necessary reading skills. Otherwise, run the entire activity as a demonstration/discussion.

   Multi-Computer Classroom: Each group should work on the experiment individually, with their own squares of material. Bring them together at the end to collect their results and to discuss their answers to the questions on Activity Sheet 3-3.

3. Each group should start by measuring room temperature. This is done by pressing RETURN to take data and leaving the thermistors sitting on the desk top. When the temperature stabilizes, press RETURN to stop taking data.

4. Each group should now tape the three thermistors to the large square of cardboard. On top of the thermistors, they should loosely tape the various squares. Be sure that they leave an air space between the material and the thermistor. On top of the white thermistor place the square of black cloth, on the blue thermistor tape the square of white cloth, and on the green thermistor tape the square of aluminum foil.

5. The cardboard should be propped up so that all three thermistors face the 100 watt light bulb in its socket. If necessary, students can take turns holding it in front of the light bulb. Care must be taken that all three thermistors are the same distance from the light bulb, and that the distance be recorded on the Activity Sheet. Students should know this is important after having done Activity 3-2.

6. Now press RETURN to start taking data. Since this experiment takes a while to run, you may find it easier to bring students to the front of the classroom at this point and either continue discussing different heat sources or switch to a different topic. The program will stop taking data after 30 minutes, and the information can be saved for later analysis if desired.

7. Have students save the data if desired, and either switch directly to ANALYZE DATA or do the analysis another day. If the data has been saved, you can direct students to analyze it by selecting ANALYZE DATA from the Main Menu and then loading the saved data.

8. Have students use the *Zoom, Select Thermistors,* and *Print All* options to answer the questions on the Activity Sheet. After the graphs have been properly labeled, they can be posted and results compared from group to group.

9. Go over the definition of radiant heat again, and if students are old enough, define heat in terms of the kinetic motion of molecules and radiant heat absorption in terms of increasing the energy of the molecules in the air captured under the squares. Have students defend variations in their graphs, particularly distance-related ones.

   Get students to describe their results in terms of the graphs, and in terms of practical applications. What color car is best to drive in the summer? Why was the outside of the Moon Lander covered with reflective material (gold foil to be specific)? What color clothes are best to wear in the summer? What color clothes do they wear in the desert? Can students think of reasons for wearing black clothes in the heat of the sun, as they do in some of the nomadic cultures? What color clothes should people who live in cold climates wear if they wish to make as much use of the sun's energy as possible?

Getting the idea:

An object's color determines how well it will absorb or reflect radiant heat. The darker materials absorb more of the heat energy, letting it eventually pass through the material to the air space beyond. Light materials absorb some of the energy and reflect some. Therefore there is less heat to pass on to the air space near the thermistors (or near your body, if the material is used as clothing). Reflecting materials, such as aluminum foil, let almost none of the heat energy through and reflect almost all of it. Thus there is little energy available to heat up the air space, and the thermistor stays nice and cool.

The molecular theory of heat suggests that heat contains energy that is given to the objects it strikes, causing their molecules to vibrate faster and thus increase in temperature. In this theory, temperature can be defined as a measure of the average kinetic energy of the molecules of a substance. Unfortunately, the ideas of molecules and of kinetic energy are very abstract, and students often cannot really understand them at an early age. Avoid using this model unless you are convinced your students can appreciate its abstractness and beauty.

Expanding the idea:

Would you get the same results if the experiment were repeated in the sunlight? What about in the sunlight on a cold day? Can you suggest ways in which the colors of the earth might affect its ability to absorb heat? What about bodies of water, are they good absorbers or good reflectors? Think about other kinds of natural surfaces: snowy banks, grassy slopes, tree-covered mountains, rock faces. What about man-made things like roads, parking lots, schools, homes, and roofs of buildings? Do they affect the heat absorbed and reflected? Can you think of an experiment to find out? Activity 4-4 asks your students to investigate their school's microclimate, and these surfaces will definitely affect that.

Activity Sheet 3-3
Why do things get warmer?

Question: What color clothing is the warmest?

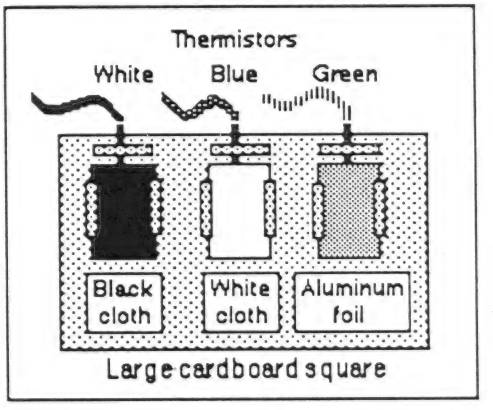
Setting up the experiment:

Step 1) Start **PLAYING WITH SCIENCE: Temperature** and select DO AN EXPERIMENT from the Main Menu. Set the Set-Up options as follows:

Range:	MAX	50°C (125°F)
	MIN	20°C (70°F)
Type of display:	Line	
Time:	20 minutes	
Number of thermistors:	3	

Step 2) Select EXPERIMENT and press RETURN.

Step 3) Start by measuring room temperature. This is done by leaving the thermistors sitting on the desk top and pressing RETURN. As soon as the temperature stabilizes, press RETURN again to stop taking data.



Step 4) Get a large piece of cardboard, at least 45 cm (18 inches) square. Tape the three thermistors to the cardboard as shown on the diagram above. Tape the pieces of material loosely on top of the thermistors in the following order:

white thermistor	square of black cloth
blue thermistor	square of white cloth
green thermistor	square of aluminum foil

Be sure to leave an air space between the thermistor and the piece of cloth covering it.

Sunburst Communications © 1988

Step 5) Prop up the cardboard so that all three thermistors face the 100 watt light bulb in the table lamp. If necessary, members of your group can take turns holding it in front of the light bulb. Make sure that all three thermistors are the same distance from the light bulb. Record the distance here: _____

Why is keeping the distance constant important?

_____
_____
_____

Gathering the data:

Step 6) Press RETURN to start collecting data. After 30 minutes stop collecting data and use the *Disk* option to save the data for later analysis. Record the file name you used here: _____

Making observations:

Step 7) Start **PLAYING WITH SCIENCE: Temperature** and select ANALYZE DATA from the Main Menu. Load the saved data by selecting your file name from the catalog and pressing RETURN.

Step 8) Use the *Zoom*, *Select Thermistors*, and *Print All* options to answer the following questions:

Temperatures under the black cloth (white thermistor)

Starting temperature _____
Ending temperature _____
Change in temperature _____

Temperatures under the white cloth (blue thermistor)

Starting temperature _____
Ending temperature _____
Change in temperature _____

Temperatures under the aluminum foil (green thermistor)

Starting temperature _____
Ending temperature _____
Change in temperature _____

Where did the heat that made the temperatures go up come from?

_____
_____
_____

Sunburst Communications © 1988

Step 5) Prop up the cardboard so that all three thermistors face the 100 watt light bulb in the table lamp. If necessary, members of your group can take turns holding it in front of the light bulb. Make sure that all three thermistors are the same distance from the light bulb. Record the distance here: _____

Why is keeping the distance constant important?

_____
_____
_____

Gathering the data:

Step 6) Press RETURN to start collecting data. After 30 minutes stop collecting data and use the *Disk* option to save the data for later analysis. Record the file name you used here: _____

Making observations:

Step 7) Start **PLAYING WITH SCIENCE: Temperature** and select ANALYZE DATA from the Main Menu. Load the saved data by selecting your file name from the catalog and pressing RETURN.

Step 8) Use the *Zoom*, *Select Thermistors*, and *Print All* options to answer the following questions:

Temperatures under the black cloth (white thermistor)

Starting temperature _____
Ending temperature _____
Change in temperature _____

Temperatures under the white cloth (blue thermistor)

Starting temperature _____
Ending temperature _____
Change in temperature _____

Temperatures under the aluminum foil (green thermistor)

Starting temperature _____
Ending temperature _____
Change in temperature _____

Where did the heat that made the temperatures go up come from?

_____
_____
_____

Sunburst Communications © 1988

Which thermometer reached the highest temperature?

_____

_____

Which thermometer showed the most rapid rise in temperature?

_____

_____

Did the temperatures stop rising? Why?

_____

_____

_____

What happens when radiant heat hits a dark-colored object?

_____

_____

What happens when radiant heat hits a light-colored object?

_____

_____

What happens when radiant heat hits a reflecting object?

_____

_____

Thinking about the results:

Step 9) What color clothes are best to wear in winter? In summer? Why?

_____

_____

_____

Why do you think the Moon Lander was covered with reflective material? _____

_____

_____

If someone asked your help in picking out a new car, what color roof would you suggest? _____

Why? _____

_____

Sunburst Communications © 1988

Classroom Lesson Plan 3-4
Why do things get warmer?

Question 3-4: In and out, can heat go both ways?

Grade level: 3-7

Equipment needed:

- **PLAYING WITH SCIENCE: Temperature** with all three thermistors.
- Sets of two small metal cans, one painted black and the other painted silver, for each group.
- Electric kettle to produce ample quantities of hot water.
- Copies of Activity Sheet 3-4 for every student.

Concepts:

- Dark objects radiate heat faster than light colored ones.
- The speed at which cooling occurs depends greatly on the difference between the temperature of the object and the surrounding temperature. The bigger the difference, the greater the cooling rate.

Objectives:

The students will be able to:

- Discuss how dark and light colored objects absorb radiant heat.
- State that dark and light objects radiate heat.
- State that the rate of cooling depends on the difference between the temperature of the object and the temperature of the surrounding air.
- State that dark colored objects cool off faster than light colored objects.

General description of the experiment:

This experiment is a direct follow up to Activity 3-3. Students will have seen that dark colored objects absorb heat faster than light colored objects. In this experiment, they will see that they also lose heat faster. Two cans, one painted black and the other painted silver act as radiant sources for heat. The cooling curves are drawn by the program and are analyzed by the students.

Classroom lesson:

1. Start the discussion by reviewing the results of Activity 3-3. Since dark objects absorb heat faster than light colored objects, students will have suggested that people living in warm climates should wear light colored clothing, and people in cold climates should wear dark colored clothing. In their search for pictures, however, they will have discovered that there are many cultures that wear dark colored clothing in very hot climates, such as the nomads in the Middle East. Eskimo's, on the other hand, frequently wear light colored clothing. Have students suggest reasons for these seemingly contradictory facts. Eventually suggest this activity as a way of deciding why people might be comfortable dressed the way they are.

2. Depending on the ages of your students and the amount of time available, either have the students paint the cans black and silver or do the job at home.

3. Start **PLAYING WITH SCIENCE: Temperature** and select DO AN EXPERIMENT from the Main Menu. Set the Set-Up options as follows:

Range:	MAX	100°C	(212°F)
	MIN	30°C	(90°F)
Type of display:	Line		
Time:	30 minutes		
Number of thermistors:	3		

   One-Computer Classroom: Gather everyone around the computer and follow the directions on Activity Sheet 3-4. Students should fill in their own copies of the Activity Sheet.

   Multi-Computer Classroom: Each group should work on the experiment individually. Bring them together at the end to collect their results and to discuss their answers to the questions on Activity Sheet 3-4

4. The green thermistor should be left to monitor room temperature. Have students fill the black and silver cans with hot water. Be sure that the cans are separated by several feet to prevent one from heating the other. Now students should put the white thermistor in the black can and the blue thermistor in the silver can. Cover the cans and press RETURN to start collecting data.

5. As the cans cool, students can come to the front of the room to continue the discussion, or read and answer the questions on Activity Sheet 3-4.

6. When the program stops collecting data, have everyone save the data, and then switch to ANALYZE DATA and use the *Zoom* and *Pick Points* options to answer the rest of the questions on Activity Sheet 3-4.

7. Did the temperature increase or decrease in each can as time went by? Are the lines straight, or did the rate at which the temperature dropped change as time went by? How does the temperature of the green thermistor compare with that of the other two?

8. Where did the heat go? Which is a better absorber of heat, dark or light colored materials? Which radiates heat the best, dark or light colored materials? If you wore a black dress, would you lose heat or gain heat? What determines which way the heat goes? What role does the surrounding temperature play in the absorption or radiation of heat. In Activity 3-3, were the surroundings warmer or colder than the air under the pieces of cloth? In this activity, were the surroundings warmer or colder than the water in the cans? What does the final temperature of the water in the cans depend on?

Getting the idea:

This investigation should directly follow Activity 3-3, "What color clothing is the warmest?" since it looked at the absorption of heat. Since objects that are good heat absorbers are also good at radiating heat, it is not surprising that the dark object wins in both activities.

One point that must be made specifically is the idea of equilibrium. If one looks closely at the graphs from this experiment and from Activity 3-3, it is easy to see that in both cases the graphs level off towards the end of the experiment. While the graph from Activity 3-3 levels off at a high temperature (the temperature of the light source) and the graph from this activity levels off at room temperature (the temperature of the surrounding air), it is easy to see that it is the surroundings that dictate the final temperature. In fact, after a while all hot objects reach an equilibrium, with the heat being absorbed equal to the heat being radiated. Thus the surrounding temperature is critical. If you do this experiment in a hot room, the final temperatures will be much higher and the curves less dramatic. The cooler the room and the hotter the water (the greater the difference), the more dramatic the curves.

From the results of this experiment, students should be able to state that the temperature of the surroundings is critical to the rate at which heat is lost. They should also realize that dark colored clothing both absorbs heat better and also radiates heat faster than light colored clothing.

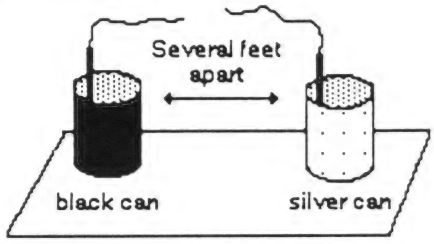
Expanding the idea:

Have students design experiments to see how the cooling curves compare when different quantities of water are placed in similar cans. They can also try to find the cooling curves for other liquids, such as detergent.

Does the color of the can make a difference? Students can try the experiment with different shades of a color, or a rainbow of colors. Does the type of paint make a difference? What about leaving an air space by putting one can inside another and using clay to seal the top. Do thermos bottles work on similar principles?

Activity Sheet 3-4
Why do things get warmer?

Question: In and out, can heat go both ways?



Setting up the experiment:

Step 1) Get two small empty metal cans, one painted black and one painted silver. Be sure that the two cans are identical in every way, except for their coloring.

Step 2) Start **PLAYING WITH SCIENCE: Temperature** and select DO AN EXPERIMENT from the Main Menu. Set the Set-Up options as follows:

Range:	MAX	100°C	(212°F)
	MIN	30°C	(90°F)
Type of display:	Line		
Time:	30 minutes		
Number of thermistors:	3		

Step 3) Select EXPERIMENT and press RETURN.

Gathering the data:

Step 4) Tape the green thermistor to the desk top. What temperature will this thermistor measure? _____

Why do you think it is necessary? _____

_____

_____

Step 5) Fill the black can with very hot water and put it on one side of the table. Fill the silver can with very hot water and put it as far from the black can as you can and still reach it with the thermistors. Why do you think it important to separate the cans? _____

_____

_____

Step 6) Put the white thermistor inside the black can, and the blue thermistor inside the silver can. Cover the cans and press RETURN to start collecting data.

Step 7) When the program stops collecting data, use the Disk Options to save your data. Then if time permits, switch to ANALYZE DATA and continue with Steps 8 and 9.

Sunburst Communications © 1988

Making observations:

Step 8) Switch to ANALYZE DATA to answer the following questions:

Did the temperature increase or decrease in each can as time went by?

_____

Are the lines on the graph straight or curved? _____

Look carefully at how the temperature measured by the blue thermistor changes. Use *Pick Points By Time* to look at the data taken every 5 minutes. Does it seem to decrease by the same amount each few minutes, or does the amount it changes seem to vary? _____

_____

_____

If the amount it changes varies, how does it vary? Is the amount of change getting larger or getting smaller? To find out, do the following:

1. Use the *Type* option to change the display to a bar graph.
2. Use the *Select Thermistors* option to look at the results of only the white thermistor.
3. Use the *Print All* option to get a copy of the graph on paper. Label the graph clearly. Which can was this thermistor monitoring, the black one or the silver one?
4. Label each of the spaces between the bars with the CHANGE in temperature. If one bar shows a reading of 65.4° and the next bar shows a reading of 62.7° then the label between these bars should be 65.4° – 62.7° or 2.7°.
5. Repeat Steps 2, 3, and 4, but this time select the blue thermistor. Which can is this graph referring to?

Is the amount of change getting larger or getting smaller?

_____

_____

Compare the results of the black can and the silver. Are the temperature changes the same or different? Which can seems to cool off fastest? _____

_____

_____

_____

Sunburst Communications © 1988

Thinking about the results:

Step 9) Where did the heat lost by the cans go? _____

_____

_____

Does the temperature of the surrounding air make a difference? How would you try to find out? _____

_____

_____

What would be the best color to paint a radiator, black or silver? Why?

_____

_____

_____

Why do some people who live in very hot climates wear black clothing?

_____

_____

_____

In Activity 3-3 you were asked to recommend a color for a car roof. What color did you suggest then? _____

Would you still make that suggestion? Why or why not?

_____

_____

_____

Sunburst Communications © 1988

Classroom Lesson Plan 3-5
Why do things get warmer?

Question 3-5: Why are gloves warm inside?

Grade level: K-3

Equipment needed:

- **PLAYING WITH SCIENCE: Temperature** with the white and blue thermistors.
- Several different pairs of gloves or mittens.
- Copies of Activity Sheet 3-5 for every student.

Concepts:

- Gloves, like any other clothing, are not warm by themselves.
- Body heat warms the air near by. If something delays heat loss, you feel warmer.
- Some kinds of materials and shapes are more effective than others at slowing heat loss.

Objectives:

The students will be able to:

- State that clothes keep you warm by preventing heat loss.

General description of the experiment:

This simple experiment demonstrates why clothes keep us warm. Students measure the temperature inside several different types of gloves, both with and without hands inside. Since the body is an excellent heat source, the glove with the hand inside will be far warmer. After all the data is collected, differences between several types of gloves are also examined.

Classroom lesson:

1. Have student bring in various mittens and gloves from home. If possible, they should bring in matched sets. Have students examine the gloves critically, looking for similarities and differences. They should divide the pile up several different ways, once by type (mittens vs. gloves), once by material (cotton vs. wool vs. synthetic), etc. Ask students to vote on which set they think will be the warmest, which the coolest. Each group will only be looking closely at one set, so be sure that samples of each of the major different types is represented.

2. Start **PLAYING WITH SCIENCE: Temperature** and select DO AN EXPERIMENT from the Main Menu. Set the Set-Up options as follows:

Range:	MAX	40°C	(100°F)
	MIN	20°C	(70°F)
Type of display:	Line		
Time:	5 minutes		
Number of thermistors:	2		

   One-Computer Classroom: This is the preferred method if you are working with students who cannot yet read. Gather everyone around one computer, preferably hooked to a large monitor, and follow the directions on Activity Sheet 3-5. Students should fill in their own copies of the Activity Sheet if they have the necessary reading ability. Otherwise, run the entire activity as a demonstration/discussion.

   Multi-Computer Classroom: Each group can work on the experiment with their mittens or gloves. Bring them together at the end to collect their results and to discuss their answers to the questions on the Activity Sheet.

3. Each group should start by measuring room temperature. This is done by pressing RETURN to take data and leaving the thermistors on the desk top. As soon as the temperature stabilizes, press RETURN to stop taking data.

4. Now each group should take one set of mittens or gloves. The white thermistor should be placed in the left hand mitten. In the right hand mitten, they should put someone's hand and the blue thermistor, making sure that the thermistor does not come in contact with the hand. Now they should press RETURN to start taking data.

5. Continue to collect data while students answer the questions.

6. When the program stops taking data, switch to ANALYZE DATA and use the *Zoom* option to answer the rest of the questions on Activity Sheet 3-5.

7. Be sure students realize that it is the hand that is acting as the heat source. Gloves are warm at least partly because our hands are inside of them, What gloves do so effectively is prevent heat loss to the outside air. The better they are at that, the 'warmer' the gloves.

Getting the idea:

The longer a hand is inside a glove, the warmer the glove will be. Certainly, this result is effectively brought home in this experiment. The temperature of the thermistor in the glove without the hand essentially remains at room temperature. Without a heat source, the temperature will not increase, regardless of the quality of the glove.

Expanding the idea:

What other articles of clothing work by preventing heat loss? What about hats, earmuffs, scarfs, and coats? Does the kind of material make a difference? Do some items keep you warm even when they are wet? Have students list articles of clothing and rate them on heat loss. Which do they think will do the best job? Which the worse job? Can they design an experiment to find out? Often we hear that clothes should be layered for maximum warmth and comfort. Why would this be good advice? What characteristics might be recommended for the different layers?

Activity Sheet 3-5
Why do things get warmer?

Question: Why are gloves warm inside?

Setting up the experiment:

Step 1) Look carefully at the pile of gloves and mittens. How are they different from each other, how are they the same? List as many possible differences as you can. Since we want to know what about a pair of gloves or mittens makes them warm, put a star beside each characteristic that you think will make a difference in keeping your hands warm.

Characteristics of different gloves and mittens	Important

Step 2) Start **PLAYING WITH SCIENCE: Temperature** and select DO AN EXPERIMENT from the Main Menu. Set the Set-Up options as follows:

Range:	MAX	40°C (100°F)
	MIN	20°C (70°F)
Type of display:	Line	
Time:	5 minutes	
Number of thermistors:	2	

Step 3) Select EXPERIMENT and press RETURN.

Gathering the data:

Step 4) Put both thermistors on the desk top and press RETURN. The program is now measuring room temperature. Do both thermistors read the same temperature? Record the measurements here:

Starting temperature, white thermistor _____
Starting temperature, blue thermistor _____

As soon as the temperature stabilizes, press RETURN again to stop taking data.

Sunburst Communications © 1988

Step 5) Get one pair of mittens or gloves. What do they look like? Describe them as best you can below.

_____
_____
_____

Step 6) Put the white thermistor in the left mitten or glove. In the right mitten or glove, put your hand and the blue thermistor, holding the thermistor near the palm of your hand. BE SURE THAT THE BLUE THERMISTOR DOES NOT COME IN CONTACT WITH YOUR HAND. Now press RETURN to start taking data again.

Making observations:

Step 7) While the program is collecting data, describe how your hand feels and let a friend make notes for you here. For example, when does your hand start to feel warm? Does one part of your hand feel warmer faster? When the program stops, you will be able to write up your own notes in the next section.

_____
_____
_____
_____
_____
_____
_____
_____
_____
_____
_____
_____
_____
_____

Step 8) Switch to ANALYZE DATA and use the *Zoom* and *Print All* options to answer the following questions:

Temperatures of the empty glove or mitten (white thermistor)
Starting temperature _____
Ending temperature _____
Change in temperature _____

Temperatures of the glove or mitten with the hand in it (blue thermistor)
Starting temperature _____
Ending temperature _____
Change in temperature _____

Which glove or mitten had the most dramatic temperature change, the one with the hand or the empty one? _____

How big was the temperature change? _____
_____

Sunburst Communications © 1988

Thinking about the results:

Step 9) Are empty gloves warm? _____

Are gloves or mittens with hands inside them warm? _____

Where do you think the heat came from? _____

_____

_____

Step 10) Compare your results with those of your classmates.

Whose gloves or mittens showed the biggest change in temperature?

_____

_____

_____

Do you think that the change is due only to the type of glove or mitten?

_____

_____

_____

How could you find out? _____

_____

_____

_____

_____

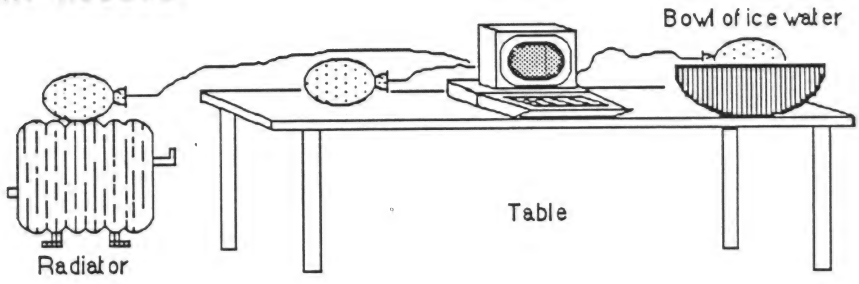
Sunburst Communications © 1988

Classroom Lesson Plan 3-6
Why do things get warmer?

Question 3-6: What happens to air when it changes temperature?

Grade level: 2-7

Equipment needed:



- **PLAYING WITH SCIENCE: Temperature** with all three thermistors.
- Three balloons of similar shape and size.
- A tray of crushed ice, or a large bowl filled with ice water, heavy on the ice.
- A radiator or other heat source, such as a bowl filled with fairly hot water.
- A copy of Chart 3-6.

Concepts:

- Air molecules move faster when they are hot and so produce more pressure.
- Air molecules move slower when they are cool and so produce less pressure.
- Moving molecules of air produce pressure, and the faster the molecules move, the more air pressure is produced. More pressure (higher temperature) makes the balloon get larger, less pressure (lower temperature) makes the balloon get smaller.

Objectives:

The students will be able to:
- Predict what will happen to the size of a balloon (or any other constant volume of air) when temperature is increased or decreased.

General description of the experiment:

In this demonstration, thermistors are placed inside of balloons which are then blown up and sealed. As the temperatures of the balloons are changed (one is heated, another cooled, while the third is the control), the students watch the heated balloon expand in size and the cooled balloon shrink. If desired, results from this experiment and from Activity 5-6 can be related. Heated air expands, and thus becomes less dense. Less dense objects rise, as we observe hot air to do. If you are interested in this aspect of temperature, do Activity 5-6 next and have students discuss how air and water behave similarly.

Classroom lesson:

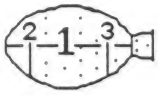
1. Place each thermistor carefully in a balloon, with the cable connecting it to the computer hanging out of the open mouth. By putting your mouth around the neck of the balloon just where the cable hangs out, it is possible to blow up the balloon. Keep the air inside by pinching the neck, about 2.5 cm (1 inch) above the end of the balloon. Now use masking tape to tightly wrap the end of the balloon. If you do this correctly, it is possible to make an air tight seal, with the thermistor inside the balloon. Repeat this procedure 2 more times, making three thermistor/balloon sets.

2. Start **PLAYING WITH SCIENCE: Temperature** and select DO AN EXPERIMENT from the Main Menu. Set the Set-Up options as follows:

Range:	MAX	50°C	(125°F)
	MIN	0°C	(32°F)
Type of display:	Line		
Time:	35 minutes		
Number of thermistors:	3		

3. Copy Chart 3-6 onto the blackboard or put it on the overhead projector. As students do the measurements, record them for all to see.

4. Have students measure the sizes of the balloons, using this diagram:



   Students should avoid squeezing the balloons while measuring. Record the measurements in the chart.

5. Press RETURN once more to start collecting data. Leave the thermistors sitting in their balloons on the desk top for about 30 seconds. As soon as the temperature stabilizes, press RETURN to stop taking data.

6. The balloon containing the white thermistor should be left sitting on the table top. The balloon containing the blue thermistor should be heated up. If it is a warm sunny day, use the extension cable to enable you to put the balloon outside. If it is a cold day, place the balloon on top of a radiator, or inside a bowl filled with hot water. The third balloon, which contains the green thermistor, should be cooled down. You can do this by placing it on a tray filled with crushed ice, or immersing it in a bowl of ice water.

7. Press RETURN to start taking data again. Wait 15 minutes to give the air inside the balloons time to change. When the 15 minutes are over, press RETURN to stop taking data. Students should record the temperatures of the balloons on the chart. They must also quickly measure the three balloons, and record this data in the spaces provided. Their observations should also be recorded.

8. Now, place the three balloons together on the table and continue to monitor their temperatures by pressing RETURN, while the class has a discussion along the following lines:
   - What happened to the air in the balloons? Did the amount of air change, or did just the space it took up change?
   - What happens to hot air? If we imagine that hot molecules move faster, what did heating the air cause the molecules to do? What happens when things move faster, do they move close together or further apart? If they moved further apart, would that explain the change in the shape of the balloon that was heated up?
   - What happens to cold air? If we imagine that cold molecules move slower, what did cooling the air cause the molecules to do? What happens when things move slower, do they move close together or further apart? If they moved closer together, would that explain the change in the shape of the balloon that was cooled?

9. Let the balloons sit on the table top for at least 15 minutes. When the program stops taking data, repeat the measurements of the balloons and record the data on the chart. Have the class answer the following questions:

   Did the balloons return to normal temperatures? What happened to their sizes? Were the changes you observed temporary or permanent? Do you think changing the temperature of air from 0°C to 80°C has a lasting effect on the air? How cold do you think it necessary to make air become a liquid?

10. Has anyone ever observed other examples of air being cooled or heated? What about balls left out overnight on very cold nights? How do hot air balloons work? Could we get the air in our three balloons hot enough to make them rise up in the air?

    There is an experiment in the **Expanding the idea** section of Activity 5-6 that explores hot air a little further. If your students are interested, you can try it here as well.

Getting the idea:

Adding heat to air adds energy, and makes the molecules move faster. As was discovered in Activity 1-2, as molecules move faster they also take up more space, causing the air to expand. They also produce more air pressure, since more molecules collide with more surfaces when the molecules are moving faster. Both of these effects make the heated balloon expand. On the other hand, when molecules are cooled, they give up heat and energy. Thus they move more slowly, collide less frequently with surfaces, take up less space, and produce less air pressure. Thus the cooled balloon shrinks. The balloon that sat at room temperature changes only if there is a leak, although it too will get smaller as air seeps out through the membrane of the skin of the balloon.

Students may report having received helium-filled balloons, and carefully bringing them home to play with the next day. By the time they wake up the next morning, however, the lift always seems to have gone out of the balloon. Helium, the gas that is used to blow up these balloons, is made of very small molecules, much smaller than those of standard room air. Thus, the seepage through the membrane of the balloon is even faster for the helium, and it will disappear into the room much faster than the normal air, which takes up most of the space in the balloon. While the balloon still looks full of air, it is full of regular room air, and cannot float any longer. Mylar balloons have much thicker skins, and will stay filled up with helium for more time than regular balloons. Something to remember the next time you visit the fair.

Expanding the idea:

If you can obtain some dry ice from the local dairy or ice store, you can use it to demonstrate some supercooling. Add alcohol to the dry ice to make a very cold liquid. Caution the students not to touch the dry ice, as it will freeze their skin instantly. Now immerse a filled balloon in this mixture (don't use the thermistors, they aren't made to measure temperatures that cold). What happens to the balloon now? How long does it take for it to get back its shape? How can you explain this change?

Chart 3-6

	Balloon 1	*Balloon 2*	*Balloon 3*
Thermistor color	_____	_____	_____
At the beginning:			
Temperature	_____	_____	_____
Length (1):	_____	_____	_____
Width (2):	_____	_____	_____
Width (3):	_____	_____	_____

	Control	*Heated*	*Cooled*
After 15 minutes:			
Temperature	_____	_____	_____
Length (1):	_____	_____	_____
Width (2):	_____	_____	_____
Width (3):	_____	_____	_____
After 30 minutes:			
Temperature	_____	_____	_____
Length (1):	_____	_____	_____
Width (2):	_____	_____	_____
Width (3):	_____	_____	_____

Observations:

Sunburst Communications © 1988

Classroom Lesson Plan 3-7
Why do things get warmer?

Question 3-7: Is there a microclimate in your classroom?

Grade level: 3-7

Equipment needed:

- **PLAYING WITH SCIENCE: Temperature** with the white and blue thermistors and the extension cable.
- Small pieces of masking tape for each group.
- Copies of Activity Sheet 3-7 for every student.

Concepts:

- Even in one room, temperature varies in different locations.
- Temperature variations can be predicted by using a logical analysis of a room's layout and architecture, and recognizing that hot air rises.
- Sensitive equipment can be used to measure small changes in temperature.

Objectives:

The students will be able to:

- State that microclimates exist within rooms.
- Predict where warm spots and cool spots will be in standard rooms. (If you wish students to meet this objective, it is desirable to do Activity 5-6 before having the students do this activity).

General description of the experiment:

Even within the closed environment of a classroom there are changes in temperature. Sunny windows create spots of warmth, floors are generally cooler than ceilings, underneath desks maybe cooler than on top. Radiators or hot air vents create other spots of warmth, open doors may be a source of cool drafts. By measuring temperatures at various locations around the room, students begin to appreciate the importance of microclimates. To predict these variations requires that students realize that hot air rises and cold air sinks, the subject of Activity 5-6. If you wish students to be able to explain the variations, do that demonstration before having them do this activity. Activity 4-4 goes one step farther and asks students to investigate the microclimate of the school yard.

Classroom lesson:

1. If you wish students to be able to predict the locations of hot spots and cold spots in a room, do Activity 5-6 first. This demonstration shows how hot water rises and cold water sinks, and can easily be broadened to imply that hot air rises and cold air sinks. These concepts are critical to the prediction of air currents in a room. If you don't have time for the whole demonstration, you can do the short experiment found under **Expanding the idea** in the same lesson.

2. Have students measure the classroom and draw a rough sketch of the layout. If you have not already done so, this is a good time to introduce the concept of scale drawings and maps. In their drawing of the classroom, be sure students clearly indicate windows, doors, heating ducts or radiators, and other large permanent fixtures. If your students are too young to make reasonable scale drawings, you may want to draw the room sketch yourself, and have them simply label the locations.

3. Ask students if they have ever noticed that some places in their house seem warmer than others. As students start to describe different locations, list them on the blackboard, with student-generated reasons for the differences. Top floors vs. bottom floors, kitchens vs. living rooms, basements vs. first floors are all places where differences should be noticeable. These variations can all be predicted, based on air flow. Now have students look around the classroom and predict where differences in temperature might be noticeable. They should record their guess on their drawing in pencil since they'll be adding in the actual temperatures later.

4. Start **PLAYING WITH SCIENCE: Temperature** and select DO AN EXPERIMENT from the Main Menu. Set the Set-Up options as follows:

Range:	MAX	45°C	(110°F)
	MIN	10°C	(50°F)
Type of display:	Bar		
Time	Ignore this option		
Number of thermistors:	2		

   One-Computer Classroom: This method works best if you are concerned with students crowding one another. Since this experiment requires the use of the extension cord to get the thermistor into as many different spots as is possible, you may have to use another extension cord on the computer itself. Gather everyone around one computer, preferably hooked to a large monitor and follow the directions on Activity Sheet 3-7. Students should fill in their own copies of the Activity Sheet and label their own copies of the room layout.

   Multi-Computer Classroom: Each group should work on the experiment individually, measuring temperatures in their part of the classroom. Bring them together at the end to collect their results and get a look at the overall picture of the classroom microclimate. You will also want to discuss their answers to the questions on Activity Sheet 3-7

5. The white thermistor should be left alone to monitor the temperature near the computer. Students should use a small piece of tape to hold it in place. Use the extension cable to extend the blue thermistor. If you are running this activity as a demonstration, use a second extension cable if available. This will permit you to reach all the corners of the room.

6. Now have students suggest where they think the room will be warmest, and measure the temperatures of these locations first. This can be done by first putting the thermistor in place (use masking tape to hold it down if necessary) and then pressing RETURN. When the temperature stabilizes, press RETURN once more to record the measurement. Have students write down the location of the thermistor and the temperature on the Activity Sheets. Continue in this manner until all the suspected 'warm spots' have been measured.

7. Students should now suggest cold spots, and repeat the procedure from Step 6. Again, students should write down the location of the thermistor and the temperature on the Activity Sheets.

8. When the entire classroom has been measured, have everyone switch to ANALYZE DATA and use the *Zoom* and *Pick Points* options to answer the rest of the questions on Activity Sheet 3-7.

9. Doing this experiment twice, once in the morning and once in the afternoon, will yield interesting results. As the room warms up from the body heat of the students and the sun light coming in through the windows, not to mention the heat if the heating system is on, the temperatures of the various cold and hot spots will change. In most cases, however, the relative locations will not change. Colder spots will stay colder, despite the general warming trend.

10. Go over the map of the room and have students try to explain why each measured hot spot exists. For some locations there may be several reasons, and this is important information as well. Are there any locations in the room that are decidedly cooler than others? Can students think of reasons for this to happen? Architects and interior designers must frequently take this kind of information into account when creating comfortable living spaces. Can your students think of some ways to improve the microclimate in the classroom?

Getting the idea:

This activity links to two others. Activity 5-6 looks at the relative density of hot and cold water, and indirectly at hot and cold air. The concept that hot air rises and cold air sinks is essential to understanding how microclimates happen. Unequal heating (vents on one side and not on another) also contributes. By exploring their classroom and recognizing that temperatures change even in such a relatively small enclosed space, students prepare for Activity 4-4, which looks at the microclimate in the schoolyard.

Temperature variations in homes can have many different sources. Upper floors are generally warmer than lower ones since heat rises. For the same reason, ceilings are generally warmer than floors. Basements are cool because cold air tends to sink, and because they are surrounded by the earth. Since earth will absorb heat (it is a large relatively cold body), it takes heat from the basement walls, which in turn absorb heat from the room. South facing windows (and walls and rooms) are generally warmer since they face some of the sun at all times. East and west facing windows are warm only in the morning and afternoons respectively. North facing windows let in lots of light, but little direct sun and thus are frequently cold. If you have a classroom that has both north and south exposures (or can combine data by using the *Link/Load* option) measure the temperatures of exposures over a period of several hours. There will be a constant and distinct difference between them.

Expanding the idea:

Have students sketch layouts of their homes, indicating predicted hot and cold spots. If standard thermometers are available, students might be permitted to check one out and use it to actually measure the temperatures. Have students suggest things in their homes that are designed specifically to equalize temperatures. Heating systems, fans, vents, and even stairwells all work to permit air to flow from one place to another, equalizing temperature as it goes.

Activity 4-4 continues this exercise by having students identify the microclimate in the school yard. You may want to do this activity next.

Activity Sheet 3-7
Why do things get warmer?

Question: Is there a microclimate in your classroom?

Setting up the experiment:

Step 1) How big is your classroom? Using tape measures and rulers, measure your classroom and make a scale drawing of it on another sheet of paper. Be sure your diagram shows the locations of windows, doors, blackboards, radiators or heat vents, and large permanent objects, such as book cases, tables, and the teacher's desk. Is anything used to break up the area of the classroom into smaller areas? If so, be sure to include them on your sketch.

Step 2) Look carefully at your diagram. Do you think the temperature is exactly the same everywhere in your classroom?

Where do you think it is the warmest? _____

Where do you think it is the coldest? _____

Step 3) Start **PLAYING WITH SCIENCE: Temperature** and select DO AN EXPERIMENT from the Main Menu. Set the Set-Up options as follows:

Range:	MAX	45°C	(110°F)
	MIN	10°C	(50°F)
Type of display:	Bar		
Time	Ignore this option		
Number of thermistors:	2		

Step 4) Select EXPERIMENT and press RETURN.

Gathering the data:

Step 5) Tape the white thermistor to the desk top. What temperature will this thermistor measure? _____

Why do you think it is necessary? _____

_____

_____

Step 6) Tape the blue thermistor to the spot in the classroom you think will be the warmest. Press RETURN to start taking data. Do both thermistors read the same temperature? _____

When the temperatures stop changing, press RETURN again to stop taking data. Record the temperatures and the location of the blue thermistor on the chart on the next page.

Sunburst Communications © 1988

Step 7) Repeat Step 6 several times, trying to pick locations that will be cooler each time. Be sure to write down a description of the location of the blue thermistor opposite each bar number to help you remember later. Some interesting spots to try include:

near windows
near doors
on the floor
near radiators
under tables
on the ceiling
near blackboards
above tables
in the corners of the room (near the floor)
in the corners of the room (near the ceiling)

Trial Number	Classroom location	Temperature of the blue thermistor
1		
2		
3		
4		
5		
6		
7		
8		
9		
10		
11		
12		
13		
14		
15		
16		
17		
18		
19		
20		
21		
22		
23		
24		
25		
26		
27		
28		
29		
30		

Sunburst Communications © 1988

Making observations:

Step 8) Switch to ANALYZE DATA and use the *Zoom* and *Pick Points* options to answer the following questions:

Where are the warmest spots in the classroom?

_____
_____
_____

Where are the coldest spots in the classroom?

_____
_____
_____

What is the biggest temperature change in your classroom?

_____
_____
_____

Thinking about the results:

Step 9) Looking at your diagram, draw lines from the sources of hot air (like the heat vents) to the other hot spots. Why do you think the hot air moved the way it did? _____

_____
_____
_____

Can you think of ways to warm up the cold spots in your classroom?

_____
_____
_____

Fans can be used to circulate the air, distributing the heat more evenly. Would a fan help in your classroom? _____

_____
_____

Think about your home. Using the results of this experiment, can you think of probable locations of hot spots and cold spots in your house? Make a list of them below. Why do you think they will be hot or cold?

_____
_____
_____
_____
_____
_____
_____
_____
_____
_____

Sunburst Communications © 1988

Classroom Lesson Plan 4-1
Learning about sunshine

Question 4-1: What happens when the sun shines?

Grade level: K-3

Equipment needed:

- **PLAYING WITH SCIENCE: Temperature** with the white and blue thermistors.
- Two pieces of white cloth.
- A sunny window and a shady spot.

Concepts:

- Sunlight is absorbed by the materials on the earth's surface and changed into heat.
- When sunlight is absorbed the temperature of the object doing the absorbing increases.

Objectives:

The students will be able to:

- Predict and describe temperature variations caused by sunshine.

General description of the experiment:

Thermistors are carefully placed in two different locations, one in the sun and the other in the shade. Temperature is monitored and compared. The increase in temperature due to the conversion of sunlight into heat is clearly evident.

Classroom lesson:

1. Since this activity is intended to introduce the idea that sunlight provides heat, there is not a great deal of pre-discussion necessary. If students have done Activity 1-4, you might want to go over some of the sources of heat.

2. Carefully select the two locations that will be used for this experiment. The shady spot must have been in the shade for at least one hour. The sunny location must have been in the sun for at least one hour also. Place the white thermistor in the shade and carefully cover it with a piece of white cloth. Place the blue thermistor in the sun and carefully cover it with the second piece of white cloth. Have students discuss why the cloth might be necessary (it cuts down on the effect of evaporation).

3. Start **PLAYING WITH SCIENCE: Temperature** and select DO AN EXPERIMENT from the Main Menu. Set the Set-Up options as follows:

Range:	MAX	50°C (125°F)
	MIN	70°C (70°F)
Type of display:	Thermometer or Digital	
Time:	5 minutes	
Number of thermistors:	2	

   Since this is a demonstration activity, gather everyone around the computer. If you have access to a large monitor, you may prefer to use the Thermometer mode to display the information. Otherwise, use the Digital mode so that the numbers will be large enough for everyone to see.

4. Press RETURN again to start taking temperatures. Record these first readings on the board for everyone to see. Now wait 5 minutes. What is happening to the temperatures? Are they going up or down? Where is heat coming from or going to?

5. Did the temperatures increase or decrease as time went by? Where was the heat coming from? Does sunlight get converted to heat when it strikes an object? How do you know?

Getting the idea:

The simple point that sunlight is converted to heat when it strikes an object is one of the first practical indications of energy transfer taking place. Make the most of this opportunity to demonstrate that the only source of heat had to be the sunlight, and that the change occurred naturally, without our having to do anything. Go from there to a discussion of other examples of sunlight changing to heat, on skin, on houses, on cars, on the earth.

The demonstration described in Activity 4-2 expands on the idea of sunlight being converted to heat and looks at rocks absorbing and re-radiating heat. It is a natural follow-up to this experiment.

Expanding the idea:

Is the radiation (sunlight) received different in summer and winter? How could you find out? Would the results of this experiment be the same if you did the experiment at a different time of year? Activity 4-4 examines the effect of angle on the amount of sunlight received and thus heat absorbed, and is easily related to seasonal differences in temperature.

Look under **Expanding the idea** in Activity 4-2 for ideas and suggestions on other activities that are closely related.

Classroom Lesson Plan 4-2
Learning about sunshine

Question 4-2: What makes rocks hot?

Grade level: K-5

Equipment needed:

- **PLAYING WITH SCIENCE: Temperature** with the white and blue thermistors.
- A shallow pan with a layer of dry sand on the bottom and some small rocks piled several layers on top.
- A sunny window.

Concepts:

- Energy from the sun is stored in rocks as heat.
- The earth absorbs heat from the sun during the day, and gives it off as radiant heat during the day, but even more so at night.

Objectives:

The students will be able to:

- State that rocks absorb heat from the sun.
- State that rocks give off or radiate that heat back into the air.
- State that the farther one gets from the rocks, the less the radiated heat can be felt.

General description of the experiment:

A pan piled high with rocks is left in a sunny window for an hour. Heat is absorbed by the rocks, and then radiated back into the air when the rocks are moved into the shade. Discussion should center around the fact that the entire earth both absorbs and radiates heat in this fashion. As a side issue, heat vs distance is explored as students move their hands away from the rocks, noting that the heat given off seems harder to detect.

Classroom lesson:

1. Since this activity is intended for use with very young students, there is not a great deal of pre-discussion necessary. If students have done Activity 1-4, you might want to go over some of the sources of heat. Students will realize that the sun provides the earth with heat, and may guess that the rocks will heat up if placed in the sun. What may surprise them is that the heat will be given back as radiant heat when the rocks are removed from the sunny spot.

2. Start **PLAYING WITH SCIENCE: Temperature** and select DO AN EXPERIMENT from the Main Menu. Set the Set-Up options as follows:

Range:	MAX	40°C (100°F)
	MIN	20°C (70°F)
Type of display:	Bar	
Time	Ignore this option	
Number of thermistors:	2	

   Since this is a demonstration activity, gather everyone around the computer. Make a copy of the following chart on your blackboard, and use it as well as the program to record the results of this activity. If students are old enough, they might also use their science notebooks to record their observations and conclusions.

Time	Room Temperature	Temperature near the rocks	Temperature a foot above the rocks	Comments
_____	_____	_____	_____	_____
_____	_____	_____	_____	_____
_____	_____	_____	_____	_____
_____	_____	_____	_____	_____

3. In front of the class, fill a shallow pan with a layer of dry sand. Place small rocks on top of the sand, building up a stack several layers thick. Place the pan in a sunny window, one that will remain sunny for at least an hour.

4. The blue thermistor will be used to measure room temperature. Tape it away from the sunlight. Be sure students understand that the temperature the blue thermistor is measuring is for comparison purposes. We want to know if the rocks change temperature and thus we need to know what the temperature would be if we were not doing this experiment.

5. Hold the white thermistor over the rocks. Press RETURN to start recording data. Count to 30 and then press RETURN to stop recording data. Have students try to answer these questions:
   - Where is it warmer, over the rocks (in the sunny window) or next to the computer?
   - How can you tell from the bars?

6. Now press RETURN again to start the second bar. Hold the white thermistor about a foot over the rocks. Count to 30 and press RETURN to stop taking data. Have students answer the following questions:
   - What is the temperature now?
   - Where is the heat coming from?
   - Where is it warmer, directly over the rocks, a foot above the rocks, or near the computer?
   - Do your students think that the temperatures will change in the course of several hours? If so, how?

7. Use the *Disk options* to save the data, and then use CONTROL-E to exit EXPERIMENT. Wait about 1 hour before continuing with Step 8.

8. Start **PLAYING WITH SCIENCE: Temperature** and select DO AN EXPERIMENT. Move the highlight to EXPERIMENT and press RETURN. Use *Load/Link* to recover the data you saved an hour earlier. Repeat Steps 4, 5, 6, and 7. Have your students discuss the following:
   - What are the temperatures now?
   - Where is it warmer, directly over the rocks, a foot above the rocks, or near the computer?
   - Where is the heat a foot above the rocks coming from?
   - Where is the heat directly over the rocks coming from?
   - Is the only source of heat the sun?

9. Again save the data. Now, move the pan with the rocks in it away from the sunny window, or block the sun using a large piece of cardboard. Wait another hour and repeat Steps 4, 5, 6, and 7. Have students answer the following questions:
   - What are the temperatures now?
   - Where is it warmer, directly over the rocks, a foot above the rocks, or near the computer?
   - Where is the heat a foot above the rocks coming from?
   - Where is the heat directly over the rocks coming from?
   - Is the sun still a source of heat?

10. The sun is a source of heat only when it shines. At night the earth needs other sources, or the temperature would drop much too fast for us to survive. Where does the heat come from at night? Is it as good a source as the sunlight? Heat released is called radiated heat. What are the two sources of radiated heat that we looked at in this experiment?

    Can students think of other examples of surfaces getting hot? What about sand at a beach or pavement in the summer? An old expression is "Hot enough to fry an egg on the sidewalk." How does this relate to our experiment?

    How did the distance between the thermometer and the rocks affect temperature? Did the heat radiated from the rocks get that high? As one goes higher in altitude, the temperature drops. Can this be related?

Getting the idea:

Rocks and sand store energy from the sun in the form of heat. When the air temperature falls below that of the rocks, they radiate the heat back into the air. This radiated heat can be easily felt directly above the rocks. As you move away from the hot surface, the amount of heat detected drops off. This is the specific subject of Activity 3-2 if your students want to measure it more precisely.

The surface of the earth absorbs heat from the sun during the day and radiates it at night when the air temperature drops. Different surfaces are better at absorbing and radiating heat, and so in the evening some places are warmer than others. Grass and trees are poor absorbers and radiators, and the woods cool off quickly. Water and cement are much better, and cities generally stay warmer at night than do forests. Large bodies of water, such as lakes and oceans, give off significant amounts of heat and produce hot air pockets. These air pockets cause winds to arise, and this explains the presence of off-shore breezes in the evenings. Areas near oceans are thus generally perceived to be cooler, because the presence of a breeze means increased evaporation (the subject of Activities 5-1 and 5-2).

This absorption and re-radiation of heat also explains another weather phenomenon. The longest day of the year in the northern hemisphere is June 21st, but the warmest days are in late July and early August. This delay is caused by the earth's continuing to give off more heat than it absorbs from the sun, even after it has had the longest exposure to the sun. This source of heat combined with that from the sun continues to warm up the air for several weeks. Eventually, the heat from the earth balances with the heat coming from the sun, and our entire hemisphere starts to cool down, beginning the temperature descent into fall and winter. Of course, the entire chain of events works the opposite way in the winter time. Then the shortest day is in December, but the earth continues to absorb more heat than it radiates until the middle of February.

Expanding the idea:

Several experiments at a higher level follow directly from this one. If your students are interested, they might try Activity 3-2: How far from a fire can you sit and still feel warm, Activity 5-1: Why do we feel cold when the wind blows?, or Activity 5-2: Can we measure the cooling effect of evaporation?

Topics to look up include weather, the water cycle, and cloud formation.

There are many children's books on weather, and while most of them won't go into much detail on some of the specific phenomena discussed in this activity, they are well worth reading. Tools for measuring rainfall, recording daily temperatures, or even measuring wind speed are available from the major science supply houses. If there is a museum with a store near you, weather "toys" are frequently sold there as well.

Classroom Lesson Plan 4-3
Learning about sunshine

Question 4-3: Which gets hotter, black asphalt or grey pavement?

Grade level: 3-7

Equipment needed:

- **PLAYING WITH SCIENCE: Temperature** with all three thermistors.
- Three shallow pans for each group. One pan of each set must be filled with white sand, another with grey sand, and the third with black sand.
- Colored sand. Obtain a good quantity of white sand and use dyes to turn about half of it black. To get the grey sand, mix a small amount of dry black sand with some of the white sand.
- A heat source, such as a heat lamp or a very sunny window.

Concepts:

- Energy received from the sun as light is stored in sand as heat.
- When sunlight is absorbed by the earth, the temperature of the soil rises.
- Dark objects absorb radiant heat better than light colored objects do, and thus get warmer faster.

Objectives:

The students will be able to:

- State light from the sun is transformed into heat when it is absorbed by rocks and sand.
- State that dark objects absorb heat better than light colored objects do.
- Hypothesize which surfaces will feel warmer based on color.

General description of the experiment:

This experiment is a variation on Activity 3-3: What color clothing is the warmest? Instead of comparing heat absorbed by different colored cloth, colored sand is used to represent different earth surfaces. Again, the darker the surface the more heat is absorbed (and re-radiated). The primary reason for doing this experiment is as an introduction to the investigation into the microclimate in the schoolyard, Activity 4-4.

Classroom lesson:

1. If your students have already completed Activity 3-3, go over those results now. Recall that the darker cloth absorbed heat better than the light cloth. Show pictures of various earth surfaces and ask if students think a similar rule might hold. Do darker colored surfaces on the earth also get warmer? Have students divide the pictures into groups, putting darker colored surfaces in one pile, lighter colored surfaces in another. What does each group have in common? Can they suggest an experiment to determine the relative heat absorption of the different surfaces?

2. Divide up the shallow pans, giving three to each group that will be doing the experiment. Have them put white sand in one, grey sand (half black and half white) in the second, and black sand in the third. They should wrap the thermistors in plastic to protect them, and then bury the white one in the pan with the white sand, the blue one in the pan with the grey sand, and the green one in the pan with the black sand.

3. Start **PLAYING WITH SCIENCE: Temperature** and select DO AN EXPERIMENT from the Main Menu. Set the Set-Up options as follows:

Range:	MAX	50°C	(125°F)
	MIN	20°C	(70°F)
Type of display:	Line		
Time:	2 hours		
Number of thermistors:	3		

   One-Computer Classroom: Use a large monitor to make the graphs visible to the entire class. Hand out a copy of Activity Sheet 4-3 to each student and let them answer the questions as the experiment proceeds.

   Multi-Computer Classroom: Each group should complete the experiment individually.

4. Have each group of students place the three pans, with the thermistors buried just under the surfaces, under the heat lamp or in a very sunny window. Press RETURN to have the computer start taking data. Set a timer for one hour so that you will be able to interrupt the experiment. While this time passes, have students leave the computers alone and continue on to something else.

5. After one hour, and without touching the thermistors, simply turn off the heat lamp and let the computer continue to record data. If you are using a sunny window as your heat source, place a large piece of cardboard between the window and the trays to prevent any more sunlight from striking the surface.

6. The program will continue to take data and graph it for another hour. When it finishes, have students save the data. During the next class period you will be able to have them analyze it.

7. At the start of the next class, have students go directly to ANALYZE DATA and load the appropriate file. Use the *Zoom* and *Pick Points* options to answer the rest of the questions on Activity Sheet 4-3.

8. Did the temperature increase or decrease in each pan as time went by? Are the lines straight, or did the rate at which the temperature dropped change as time went by? Which color was better at absorbing the heat? Which color was better at re-radiating it back when the heat lamp was turned off?

Getting the idea:

This investigation is very similar to those described in Activities 3-3 and 4-2. In Activity 3-3: What color clothing is the warmest?, dark cloths turned out to be better heat absorbers. Thus it is logical to expect that the black sand will be the better heat absorber in this experiment. In Activity 4-2: What makes rocks hot?, re-radiation of heat is observed. In this experiment, both behaviors are observed and watched long enough to make some interesting comparisons possible. Detailed analysis is possible because of the length of the experiment and the clearly defined differences between the objects under study.

Just as in Activity 3-4, the idea of equilibrium is essential. If one looks closely at the graphs from this experiment, it is easy to see that the graphs level off twice, once just before the heat lamp is turned on and again just before the end of the experiment. What we are seeing is that at some point the heat being absorbed becomes equal to the heat being radiated. The surrounding temperature is critical. If you do this experiment in a cold room, the final temperatures will be much lower and the curves more dramatic. The greater the difference between the object's temperature and the room's temperature, the more dramatic the curves will be.

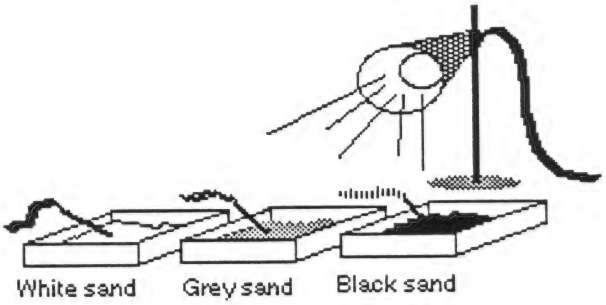
It is easy to go from this experiment to the analysis of microclimate in Activity 4-4. The darker the surface, the hotter it will be, given equal amounts of light. On a windless day, these differences are quite measurable. Most students will have had practical experience with walking barefoot across roadbed on a hot summer day. While they probably made no effort to measure the differences, grass and pavement offer quite a different feel to bare feet.

Expanding the idea:

Have students look at photographs of houses, cities, parks, beaches, and other types of terrain. They should be able to predict hot spots and cold spots, just from color and surface texture. If possible, obtain a set of satellite photographs showing temperature measurements over the surface of the earth. Why are cities so much warmer than countryside? Is the increased population *sufficient* to explain the difference, or are there other possibilities? Does surface texture make a difference? Have students design an experiment to find out.

Activity Sheet 4-3
Learning about sunshine

Question: Which gets hotter, black asphalt or grey pavement?



Setting up the experiment:

Step 1) Get three shallow pans. Fill one with white sand, fill the second one with grey sand, and fill the third with black sand.

Step 2) Wrap all three thermistors in plastic, and then bury them just below the surface of the sand. Put the white thermistor in the pan with white sand, the blue thermistor in the pan with grey sand, and the green thermistor in the pan with the black sand.

Step 3) Start **PLAYING WITH SCIENCE: Temperature** and select DO AN EXPERIMENT from the Main Menu. Set the Set-Up options as follows:

Range:	MAX	50°C (125°F)
	MIN	20°C (70°F)
Type of display:	Line	
Time:	2 hours	
Number of thermistors:	3	

Step 4) Select EXPERIMENT and press RETURN.

Gathering the data:

Step 5) Put the three pans in front of a heat source. Be sure that they are all the same distance from the light. Press RETURN to start collecting data.

Step 6) After one hour without disturbing the thermistors in any way, remove the heat source. Continue taking measurements for another hour.

Step 7) When the program indicates that it has finished taking measurements, use the *Disk options* to save the data. Record the file name that you use here: _____

Sunburst Communications © 1988

Making observations:

Step 8) Use **PLAYING WITH SCIENCE: Temperature** and select ANALYZE DATA from the Main Menu. Use the *Zoom*, *Pick Points*, and *Print* options as needed to fill in the chart and answer the questions below.

Sand Color	Starting Temperature	Highest Temperature	Difference Highest - starting	Ending Temperature	Difference Highest - ending
White	_____	_____	_____	_____	_____
Grey	_____	_____	_____	_____	_____
Black	_____	_____	_____	_____	_____

Step 9) Zoom in on the first half of the experiment. Use *Pick Points By Time* to look at points at intervals of 5 minutes. Use *Print Screen* to get a copy of the graph. Attach the graph to this worksheet and indicate the starting temperature of each of the pans. Also label the highest temperature of each pan. Was there a time when the temperatures stopped changing? If so, label that as well.

Step 10) Using your graph, and the *See Data* option if necessary, answer the following questions:

When the experiment started, were the temperatures of the sand in the three pans close to the same? _____

Should they have been the same? If they weren't the same, can you suggest some reasons for the difference? _____

_____

_____

_____

What are the highest temperatures reached by the sand in the three pans? Record these, and the difference between the starting and highest temperatures on the chart above.

For which color sand was the difference between the starting and the highest the greatest? _____

_____

_____

_____

For which color sand was the difference between the starting and the highest the least? _____

_____

_____

_____

Step 11) Zoom in on the second half of the experiment. Use *Pick Points By Time* to look at points at intervals of 5 minutes. Use *Print Screen* to get a copy of the graph. Attach the graph to this worksheet and indicate the highest temperature of each of the pans. Also label the ending temperature of each pan. Was there a time when the temperatures stopped changing? If so, label that as well.

Sunburst Communications © 1988

Step 12) Using your graph, and the *See Data* option if necessary, answer the following questions:

When the experiment ended, were the temperatures of the sand in the three pans close to the same? _____

Should they have been the same? If they weren't the same, can you suggest some reasons for the difference? _____

_____

_____

What are the ending temperatures reached by the sand in the three pans? Record these and the difference between the highest and ending temperatures on the chart above.

For which color sand was the difference between the highest and the ending temperature the greatest? _____

For which color sand was the difference between the highest and the ending temperature the least? _____

Thinking about the results:

Step 13) Looking at the results of this activity, and the results of Activity 3-3 if you did that one, can you make a statement about the difference between dark colored objects and light colored objects? Be sure to relate the ability of the objects to absorb heat and to radiate it back into the air in your statement. _____

_____

_____

_____

_____

How do you think the difference affects temperatures near black topped roads? Should these roads be hot or cold? _____

_____

How do you think temperatures near grey pavement compare to temperatures near black topped roads? Which would be hotter?

_____

_____

Predict relative temperatures near bare earth (dark brown), grass (green), and white sand. Which would be the hottest, the coolest, and in the middle? _____

_____

_____

Does texture make a difference? Grass is usually rougher than pavement – does that help make it feel cooler? _____

How could you find out how texture affects temperature?

_____

_____

_____

_____

_____

Sunburst Communications © 1988

Classroom Lesson Plan 4-4
Learning about sunshine

Question 4-4: Where is the warmest place to sit in the school yard?

Grade level: 3-7

Equipment needed:

- Standard thermometers, one for each group of students.
- Three large scale maps of the school yard. These can be made from student drawn maps and enlarged using a copier.
- One meter stick or yard stick for each group.
- Copies of Activity Sheet 4-4 for every student.
- *Optional:* **PLAYING WITH SCIENCE: Temperature** with the white thermistor and the extension cable.

Concepts:

- Even in a small geographic area, temperature varies in different locations.
- Temperature variations can be predicted by using a logical analysis of a location's physical layout, and by recognizing the effects of sunlight on different surfaces.
- Sensitive equipment can be used to measure fairly small changes in temperature.

Objectives:

The students will be able to:
- State that microclimates exist within small geographic areas.
- Predict where warm spots and cool spots might be found by applying some of the concepts learned in earlier activities.

General description of the experiment:

Even within the restricted environment of a standard school yard there are changes in temperature. By measuring temperature at various locations around the yard, students begin to appreciate the importance of microclimates. To predict these variations requires that students realize that hot air rises and cold air sinks (Activity 5-6), that dark surfaces will radiate heat back into the air (Activities 3-3 and 4-3), and that silvered or flat white surfaces reflect heat when light shines on them (Activities 3-3 and 3-4).

Classroom lesson:

1. If you wish students to be able to predict the locations of hot spots and cold spots, do Activities 3-3, 3-4, and 5-6 first. These activities will build the concepts needed to generalize to a larger area like a school yard.

2. Have students measure the school yard and draw a rough sketch of the layout. Have them use a compass to determine directions. If you have not already done so, this is a good time to introduce the concept of scale drawings and maps. In their drawings of the school yard, be sure students clearly indicate windows, doors, air ducts, sharp corners, and, most importantly, the types of surfaces found. Do not do this activity if your students are too young to make reasonable scale drawings. While you could sketch the yard yourself, a lot of the fun of this activity will be lost for the students.

3. Ask students if they have ever noticed that some places seem warmer than others. As students start to describe different locations, list them on the blackboard, with student-generated reasons for the differences. Locations such as sunny corners, wood porches or concrete porches, under shade trees, or in the middle of parks are all likely to be at different temperatures on the same day. These variations can all be predicted, based on air flow and surface type. Now have students look around the school yard and predict where differences in temperature might be noticeable. They should record their guesses on their drawing in pencil, since they'll be adding in the actual temperatures later.

4. The actual taking of measurements must be done on a sunny day, preferable windless. Since you will be comparing temperatures around the yard, assign student groups different areas to measure at the same time. This can be done by taking one of the sketches from Step 2 and photocopying it. Use a marker to draw lines on the sketch, and label the sections with group names.

5. Students will be taking temperatures all around the school yard. If you have sufficient standard thermometers, it is easier to use them than to use the computer. If you want to use the computer to double check temperatures, or to distinguish between locations that have similar temperatures, you will first have to get a very long extension cord and a sturdy cart.

6. If you plan to use **PLAYING WITH SCIENCE: Temperature**, start it now and set the Set-Up options as follows:

Range:	MAX	45°C	(110°F)
	MIN	10°C	(50°F)
Type of display:	Digital		
Time:	1 hour		
Number of thermistors:	1		

Attach the extension cable to the white thermistor. If you have more than one extension cable, use them also, since you will want to be able to move the thermistor about as freely as possible. Press RETURN to start taking measurements whenever you have the thermistor in a likely place. Wait until the temperature stabilizes and then press RETURN to stop. Record the measurement on the chart provided in Activity Sheet 4-4.

7. Divide students into groups of two or three and give them sections of the school yard to measure. Before letting them begin, go over the following procedures so that results will be consistent enough to compare.

   Temperatures above different surfaces types should be measured at three different heights:

   - Close to the ground – hold the thermometers about 2.5 cm (1 inch) above the surface, count to 60 and record the temperature.
   - 1 meter (1 yard) above the ground – brace the thermometer against the top of the meter stick, count to 60 and record the temperature.
   - 2 meters (2 yards) above the ground – hold the thermometer as high as you can reach, count to 60 and record the temperature.

8. Students should now separate into their groups and make their measurements. There is space on Activity Sheet 4-4 to record temperatures in 20 different locations. If your school yard is very large, you may need additional copies of this chart to record all the information.

9. Have students combine their information onto three large sketches of the school yard. One sketch should show temperatures close to the ground, the second should show temperatures 1 meter (1 yard) above the ground, and the third should show temperatures 2 meters (2 yards) above the ground.

10. Go over the maps of the school yard and have students try to explain why each measured hot spot exists. For some locations there may be several reasons, and this is important information as well. Are there any locations in the yard that are decidedly cooler than others? Can students think of reasons for this to happen? Does temperature vary according to measured height? Can your students think of reasons for this to happen? How do the suggested hot spots (Step 3) compare with those measured? Were there any surprises? Can your students think of some ways to improve the microclimate in the school yard? Where is the warmest place to sit on a sunny day? Where is the coolest place?

11. Doing this experiment twice, once in the morning and once in the afternoon, will yield interesting results. As the school yard warms up from the heat of the sun, the temperatures of the various cold and hot spots will change. In most cases, however, the relative locations will not change. Colder spots will stay colder, despite the general warming trend.

Getting the idea:

This activity links several others. Activity 5-6 looks at the relative density of hot and cold water, and indirectly at hot and cold air. The concept that hot air rises and cold air sinks is essential to understanding how microclimates happen. Activities 3-3 and 4-3 look at the contribution of surface color to heat, another important factor.

Temperature variations have many different sources. Besides artificial sources like heat vents, black surfaces will absorb heat from the sun and re-radiate it later. Shiny surfaces reflect heat, making the air nearby seem much warmer. Corners protect air from drafts, giving it more time to warm up. Have students explain observed hot spots and cold spots by suggesting as many reasons as they can think of. Have them think about the sun's position in the sky as well. Does the direction a wall faces make a difference? Can students use their maps to demonstrate the differences?

Expanding the idea:

Examining microclimates can be done in any location, provided the boundaries have been clearly marked. Students may want to determine the microclimate around their homes and decide on the best place to sit in the sun, to be cool in the summer, to be warm in the winter. If they had to build a small garden, where would they put it? Why?

Activity Sheet 4-4
Learning about sunshine

Question: Where is the warmest place to sit in the school yard?

Setting up the experiment:

Step 1) How big is your school yard? Using tape measures, rulers, and a compass, measure your school yard and make a scale drawing of it on another sheet of paper. Be sure your diagram shows the locations of windows, doors, air ducts, sharp corners, and, most importantly, the types of surfaces found. Is anything used to break up the area of the yard into smaller areas, such as trees, fences, or paved areas? If so, be sure to include them on your sketch.

Step 2) Look carefully at your diagram. Do you think the temperature is exactly the same everywhere in your school yard? _____

- Where do you think it will be the warmest? _____
- Where do you think it will be the coldest? _____

Gathering the data:

Step 3) With your group, measure the temperatures in the area of the school yard assigned to you. Be sure to measure the temperatures three times for each location to be tested.

- Close to the ground - hold the thermometers about 2.5 cm (1 inch) above the surface, count to 60 and record the temperature.
- 1 meter (1 yard) above the ground - brace the thermometer against the top of the meter stick, count to 60 and record the temperature.
- 2 meters (2 yards) above the ground - hold the thermometer as high as you can reach, count to 60 and record the temperature.

Step 4) Record all measurements carefully on the chart. Number the locations on your map, and use the numbers to refer to the temperatures as well. The note column is useful if you need to jot down some information about the type of surfaces that you think may have affected the temperatures.

Step 5) Following your teacher's directions, record your measurements on the large map shared by the entire class. Can you see a pattern emerging?

_____
_____
_____
_____

Sunburst Communications © 1988

Making observations:

Step 6) Where are the warmest spots in the yard?

Where are the coldest spots in the yard?

Between which two adjacent locations did the temperature change the most?

Thinking about the results:

Step 7) Looking at your diagram, try to think of a reason for any temperature changes you or your classmates observed.

Does temperature vary with distance from the surface?

At which distance (2.5 cm, 1 meter, or 2 meters) from the ground was temperature the most uniform over the entire school yard?

Can you think of reasons for this to be so?

Looking carefully at the map, can you make some general statements as to which surfaces will be warmer in general then others? What about surfaces that will generally be colder?

Think about your home. Using the results of this experiment, can you think of probable locations of hot spots and cold spots in your own yard? Make a list of them below. Why do you think they will be hot or cold?

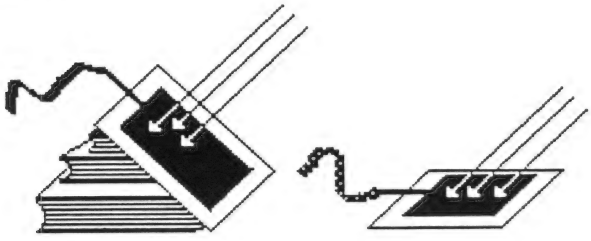
Sunburst Communications © 1988

Location on map	Temperature near the ground	Temperature 1 meter above the ground	Temperature 2 meters above the ground	Notes

Sunburst Communications © 1988

Classroom Lesson Plan 4-5
Learning about sunshine

Question 4-5: Why is it colder in the winter time?



Grade level: 2-7

Equipment needed:

- **PLAYING WITH SCIENCE: Temperature** with the white and blue thermistors.
- Two pieces of corrugated cardboard covered loosely with black paper.
- A pile of books to support one piece of cardboard at a 45° angle.

Concepts:

- During the winter months, the part of the earth we live on is tilted away from the sun, resulting in sunlight striking the surface at oblique angles.
- When rays of light from the sun strike the earth's surface at an oblique angle, less heat is available to be absorbed by the earth.
- The earth's tilt away from the sun during our winter also results in shorter days, and thus less time is available for sunlight to warm up the surface.

Objectives:

The students will be able to:
- State that cooler weather in the winter time is due to shorter days and sunlight striking the surface at an oblique angle.
- When light strikes surfaces at an oblique angle, less heat is created.

General description of the experiment:

Explaining the seasons to young students is a fairly difficult task. Demonstrations such as this one help illustrate ideas that are very hard to understand. While students are willing to believe that the earth is tilted away from the sun in the winter time, realizing the enormous difference that it makes to the amount of heat received is harder to understand. Thermistors covered by black paper are placed in a sunny spot. One piece of paper is laid flat on the table and represents the earth's surface. The other piece is held up at right angles to the sunlight, and maximizes the amount of light received. Naturally, this piece of paper will get warmer much faster.

Classroom lesson:

1. Start the discussion by asking students why they think that the winter is colder than the summer. Most will realize that the days are much shorter, and will willingly believe that therefore less sunlight falls on the earth, less heat is absorbed, and the air stays colder. The more important effect, that of sunlight striking the surface at an increased angle, is much harder to demonstrate. If you have a model of the sun/earth system, use it to show how the part of the earth we live on tilts towards the sun during our summer, and away from the sun during our winter. Then do the following demonstration to illustrate the importance of that tilt.

2. Put two pieces of black paper lightly on top of two squares of corrugated cardboard. Place one piece flat on a table in a very sunny spot. Prop up the other one so that it faces directly into the sun. Slide the white thermistor under the paper on the flat piece of cardboard and use tape to fasten the blue thermistor under the paper on the tilted piece. Identify the flat piece as being the earth's position relative to the sun in winter, and the propped-up piece as the earth's position during the dog days of summer.

3. Start **PLAYING WITH SCIENCE: Temperature** and select DO AN EXPERIMENT from the Main Menu. Set the Set-Up options as follows:

Range:	MAX	50°C	(125°F)
	MIN	20°C	(70°F)
Type of display:	Thermometer or Digital		
Time:	10 minutes		
Number of thermistors:	2		

   Since this is a demonstration, gather everyone around the computer. If you have access to a large monitor, you may prefer to use the Thermometer mode to display the information. Otherwise, use the Digital mode so that the numbers will be large enough for everyone to see.

4. Press RETURN again to start taking temperatures. Record these first readings on the board for everyone to see. Now continue to write down the temperatures of the thermistors every 2 minutes. What is happening to the temperatures? Are they going up or down? Where is heat coming from or going to? Is the amount of heat received the same?

5. Did the temperatures increase or decrease as time went by? Where was the heat coming from? Does sunlight get converted to heat when it strikes an object? How do you know? Does the angle make a difference to the amount of sunlight available to convert to heat? How do you know?

Getting the idea:

This demonstration fits nicely into a unit on weather or astronomy. Even older students rarely appreciate how important the angle between the earth and the sun actually is. If student interest warrants, you can extend this demonstration by trying a variety of different angles. Which is the best? The worst?

Expanding the idea:

There are many sources of information on the movement of the earth around the sun and on the tilt of the earth and sun. Most science resource centers have at least one model of the sun/earth system, or at least a globe of the earth that can be lighted up with a flashlight to demonstrate the reason for day and night. A visit to a planetarium is a valuable activity, if students have been properly prepared and the planetarium expects young students.

Classroom Lesson Plan 4-6
Learning about sunshine

Question 4-6: What is the weather in your classroom like?

Grade level: 1-7

Equipment needed:

- **PLAYING WITH SCIENCE: Temperature** with the white and blue thermistors.

Concepts:

- Temperature in the classroom changes during the day and from day to day.
- Daily records can be used to predict future weather patterns, or support explanations for observed patterns.

Objectives:

The students will be able to:
- Predict classroom temperatures based on observed patterns.
- Use daily logs as evidence to support explanations.

General description of the experiment:

Over a period of a month, a daily weather journal is kept, and as one component of the journal, classroom temperature is monitored. By comparing the classroom temperature with observed outdoor weather, students will be able to predict future weather patterns.

Classroom lesson:

1. This activity is meant as part of a standard weather unit. Students should be keeping a daily journal of observed weather, including daily maximum and minimum temperatures. Newspapers, outdoor thermometers, or even a phone in weather report can be used as a source for most of the information. **PLAYING WITH SCIENCE: Temperature** is used to supply the hardest to measure data, temperatures local to the classroom itself.

2. Make a large wall chart with space for the following daily information:
   - Morning outdoor temperature
   - Morning indoor temperature
   - Major weather pattern (rainy, cloudy, sunny, snow, etc.)
   - Afternoon outdoor temperature
   - Afternoon indoor temperature

3. Carefully thread the white thermistor out the classroom window. Make sure it is well clear of the walls of the building before taking any measurements. Place the blue thermistor along side the computer.

4. On the morning of the day that you start this activity, start **PLAYING WITH SCIENCE: Temperature** and select DO AN EXPERIMENT from the Main Menu. Set the Set-Up options as follows:

Range:	MAX	40°C	(100°F)
	MIN	10°C	(50°F)
Type of display:	Bar		
Number of thermistors:	2		

   Use a large monitor to make the information easily visible. Have each student keep a weather journal, or have everyone take a turn filling in the wall chart.

5. Press RETURN to measure the temperatures. Record them on the wall chart as well. Press RETURN again to stop taking data and save the data.

6. In the afternoon, just before school ends, boot up the program again, and go directly to EXPERIMENT. Use *Link/load* to load in the data you saved in the morning. Again take the outside temperature with the white thermistor and the inside temperature with the blue one by pressing RETURN once to start recording the data and again to stop. Save the data again.

7. Now, every morning and afternoon for the next month, boot up **PLAYING WITH SCIENCE: Temperature** and go directly to EXPERIMENT. Use *Link/Load* to restore the data from the previous day, and record the new trial numbers. Take temperature measurements following the directions in Step 6. Gradually you will build up a database of temperatures, with all the odd measurements being morning temperatures and all the even ones being evening ones. You will be able to continue taking data in this fashion for twenty school days. At this point, stop the experiment and begin discussing the results with your students.

8. Go directly to ANALYZE DATA from the Main Menu and load the appropriate file. Use the *Zoom* and *Select Thermistors* options to help students answer the questions in the post-experiment discussion.

9. Discuss the following questions with the students:

   Was the classroom always the same temperature in the mornings? How much did the temperature vary over the 20 days? Was the outside temperature the same every morning? How much did that temperature vary over the 20 days? What are the sources of heat in the classroom? Does the heating system in your school work evenly? Can you defend your answer?

   Was the classroom always the same temperature in the evenings? How much did the temperature vary over the 20 days? Was the outside temperature the same every evening? How much did that temperature vary over the 20 days? During the day, what are the sources of heat in the classroom?

   Does the temperature outside effect the temperature inside? How can you prove your answer? Does the temperature inside effect your ability to function? Can you defend your answer to that question?

   Does the kind of weather (cloudy, rainy, etc.) affect the temperature outside? Is there a pattern you can see? What is it? Does the kind of weather affect the temperature inside? Is there a pattern?

Getting the idea:

Keeping daily weather logs has always been a popular classroom activity. Unfortunately, the temperatures reported in the newspapers and on the radio are often different from those measured near the classroom. This activity gives students the opportunity to compare these conflicting results. It also lets them explore relationships between inside and outside temperatures. Because of the inefficiency of school heating systems, there is usually a delay between major changes in outdoor conditions and subsequent adjustment of indoor conditions. If such an situation occurs, be sure to point it out to students. Knowing that delays occur is an important concept if students are to appreciate the skill needed to produce ideal living conditions.

Expanding the idea:

Continue monitoring the weather over a longer period of time. Once a week for a year will generate some very interesting results. If students are old enough, you can even suggest in September that they keep a journal for the year. Including sun and moon positions will add additional interesting data that can be explored in a unit on weather, physics, or even astronomy.

Classroom Lesson Plan 4-7
Learning about sunshine

Question 4-7: Can you build a solar cooker?

Grade level: 4-7

The following directions for making a solar cooker come from *Scienceworks, an Ontario Science Centre Book of Experiments*, pages 28-29. It is published by Kids Can Press, Toronto, Ontario, Canada, 1984.

Any unit of measurement can be used to build the solar cooker, centimeters, meters, inches, feet, etc. The important thing is to keep everything in proportion. This project, while not exactly a classroom activity, is an excellent project idea. Have advanced students work on it as supplemental activity, or do it yourself and use it to demonstrate the power of solar energy.

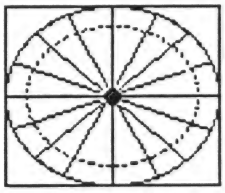
Equipment needed:

- Corrugated cardboard 100 units square for the base.
- Several smaller pieces of corrugated cardboard for the ribs of the cooker.
- Pencil, protractor, scissors, pins, and glue for construction tools.
- Aluminum foil to act as a reflecting surface.

Directions for making a solar cooker:

1. From corrugated cardboard, draw and cut out a circle with a radius of 50 units.

2. Inside the circle, draw and score (by cutting halfway through) a 45 unit radius circle.

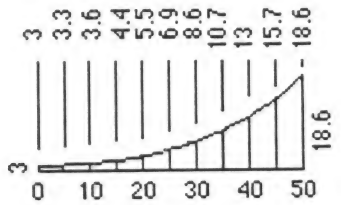


Base (1)

3. Using a protractor, divide the circle into sixteen 22.5° sections. Then cut a slit from the outside to the scored circle.

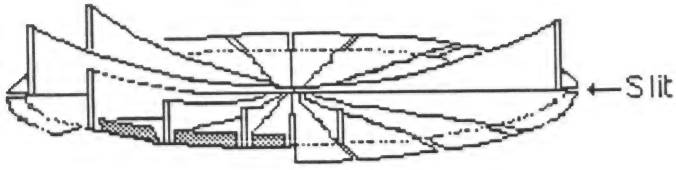
4. Turn the circle upside down. Bend the scored ends upwards.

5. Cut out a rib on the the other cardboard, using the measurements on the drawing. Trace it and cut out 15 more. You now have 16 identical ribs.

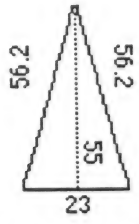


Ribs (16)

6. Glue the bottom edge and slip each rib into a slit. Hold them in position with pins until they're dry.



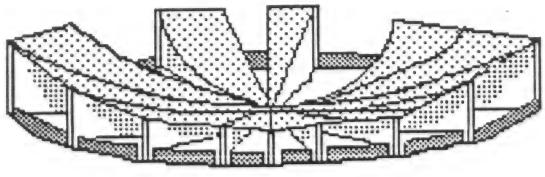
7. Cut sixteen triangles the size shown from extra pieces of cardboard.



Triangles (16)

8. Cover each triangle with aluminum foil, shiny side up, and glue the foil down.

9. Glue eight triangles to the ribs. Each triangle fits over two ribs and covers one section. Wait for the glue to dry.



10. Cover the empty sections by gluing the eight remaining triangles to the ones already in place.

11. Your solar cooker is ready. To find the hot spot, place the cooker in the sun and hold a piece of paper directly above the center of the bowl. Move it up and down slowly until you find the hot spot. You can use the cooker to cook a hot dog on a stick or roast a marshmallow. Do not put the thermistors in the hot spot, as it can become much hotter than they are designed to withstand.

Getting the idea:

The solar cooker is a parabolic reflector, just like the dish in a telescope. This shape will focus light or heat or even sound very well. In fact, you can use the same directions to make a very effective listening device. The focal point of the dish, determined by the shape and size, will be about 40 units above the center.

Classroom Lesson Plan 5-1
Learning about water

Question 5-1: Why do we feel cold when the wind blows?

Grade level: 1-5

Equipment needed:

- **PLAYING WITH SCIENCE: Temperature** with the white thermistor.
- A small amount of room temperature water.

Concepts:

- Dry objects are room temperature do not change temperature if they are moved rapidly.
- When water evaporates (becomes a gas) it has to take heat from somewhere.
- The effect of water's evaporating on a surface is to cool it down.
- Rapid movement cools wet things down by speeding the rate of evaporation.

Objectives:

The students will be able to:
- State that evaporation results in cooling.
- State that sweat is an example of the body using evaporation to cool itself.

General description of the experiment:

Students are asked to hypothesize what will happen when a dry thermistor is whirled around the demonstrator's head. Since most know that wind has a chilling effect, they naturally assume that the temperature will drop. After everyone has a chance to make a guess, the experiment is conducted. To everyone's surprise, the temperature will remain quite constant. After everyone is asked to explain this result, the experiment is repeated with a wet thermistor. This time the temperature does drop as expected. This experiment is a very graphic way to introduce the idea of cooling through evaporation.

Classroom lesson:

Successful presentation of this investigation requires plenty of discussion. Encourage students to suggest what will happen before trying the experiment, and to back up their suggestions with explanations. Don't worry about the vocabulary they use – hypothesis testing is the most important aspect of this activity.

Make this activity a guessing game. Be sure to give everyone equal time, even if they make seemingly 'silly' suggestions. Their ideas are based on their understanding of what will happen, and by knowing what they think, you stand a better chance of convincing them of what really takes place.

1. Have everyone in the class whirl their hands around their heads in a big circle. Do their hands feel cooler or warmer?

2. Encourage your students to hypothesize about why their hands feel different when they whirl them around their heads. List possible reasons on the blackboard for all to see.

   Do students notice a different feeling about their arms? What is it and why do they think it feels this way?

2. Start **PLAYING WITH SCIENCE: Temperature** and select DO AN EXPERIMENT from the Main Menu. Set the Set-Up options as follows:

Range:	MAX	100°C	(212°F)
	MIN	0°C	(32°F)
Type of display:	Digital		
Time:	15 minutes		
Number of thermistors:	1		

3. Select EXPERIMENT and when the EXPERIMENT screen appears, press RETURN again to start taking data.

4. Leave the dry thermistor lying on the counter for a few moments while it comes to room temperature. Record room temperature on the blackboard. If you have not already discussed the meaning of room temperature, now is a good time to do so.

5. *Before touching the thermistor* – Ask for suggestions of what will happen to the temperature of the thermistor if you whirl it around your head. Record the suggestions and brief explanations on the blackboard for later reference.

   There will probably be at least two groups of opinions. Some of your students will naturally conclude that the temperature will go down. Others may suggest that air friction will cause the temperature to rise. Don't attempt to pre-judge their suggestions, just try to get them to give you an explanation of their opinions. If possible, have them base their explanations on observations made outside of the classroom.

6. Now, while the program is monitoring the temperature, whirl the thermistor around your head. The temperature should not change more than a few tenths of a degree.

7. Go back over their hypotheses and ask students to try and explain the difference between their original suggestion and the facts. If they backed up their original answers with observations, remind them that the observations are still correct. The problem lies in the conclusion drawn from the observations.

   Reconciling facts with hypotheses and conclusions is one of the most difficult aspects of science. Knowing what facts are relevant to a given situation is the result of practice in listing all the possibilities and then eliminating those that don't really apply.

8. Sooner or later, one of your students will mention that they always feel cool when they leave a swimming pool or the bath tub. This is your clue to stop the discussion and wet the thermistor. Whirl it around your head. What happens to the temperature now?

9. Again, look back at the hypotheses generated by the class and identify those that included observations that mentioned moisture. If no one mentioned it, discuss the importance of examining a situation for all possible contributing factors before drawing a conclusion.

10. If your class is ready for it, finish up the lesson with a short discussion on cooling by evaporation. You can find some additional information in **Getting the idea**.

Getting the idea:

Spend time after this activity discussing the results. In light of what your class has just discovered, can the students answer the question: Why do we feel cold when the wind blows? Be prepared for students to suggest that whirling the thermistor will warm it up. Air friction is not really important here, but the exposure to the space age has made even very young people aware of the problems of air friction.

When you whirl your hand around your head, two different things occur. The action of whirling your hand (a physical activity) causes blood to flow a bit quicker, and some of your students may think their hand warms up. At the same time, the moisture on your hand will evaporate as it is whirled, and the surface of your palm should cool off. Very sensitive people may even notice both effects, the lower arm getting warm, the palm cooling off.

If the dry thermistor is at room temperature when you whirl it, there should be no apparent change in temperature. The air is the same temperature as the thermistor, and air friction is minimal at the speed at which you can whirl a thermistor. If you could increase the speed substantially, air friction would have an effect and the thermistor would show an increase in temperature.

If you wet the thermistor with your tongue, the temperature will go up because your body is much warmer than room temperature. For this reason, it is important to use room temperature water if possible. When the wet thermistor is whirled, a very dramatic cooling effect is seen. The water on the surface of the thermistor evaporates (becomes air vapor, a gas), and in doing so takes heat from the most convenient source, the thermistor itself. Thus, the thermistor cools off. If you wet your hand or your body and stood in a windy spot, exactly the same effect would occur. The wind would cause the water on the surface of your body to evaporate quickly and the natural cooling effect to be more noticeable.

When we sweat, we are actually trying to cool off our body. The liquid on the surface of our skin (mostly water) slowly evaporates, taking heat from our body to help become a gas. Thus, a sweating body is actually a naturally cooling one! When a dog gets hot, it can't sweat the way we do since it has a fur coat and no sweat glands. Instead, dogs sweat by panting. As the water evaporates off the dog's tongue, his body is naturally cooled.

Expanding the idea:

Can your students think of other examples of natural cooling. Discuss living in a very hot climate and a very cold one. Do different people react differently to getting wet and then standing in a windy place? Do different people sweat differently? You might want your students to do Activity 2-4. This is an experiment on hand temperature, and hand moisture is important here, too. What about having students design an experiment to quantitatively measure the effect of wind on different objects? Activity 5-2 develops this idea further.

Classroom Lesson Plan 5-2
Learning about water

Question 5-2: Can we measure the cooling effect of evaporation?

Grade level: 3-7

Equipment needed:

- **PLAYING WITH SCIENCE: Temperature** with the white and blue thermistors.
- A small electric fan, or a group of students willing to fan one of the thermistors for several minutes.
- A pan of room temperature water.
- 2 cotton balls per group doing the experiment.
- Copies of Activity Sheet 5-2 for each student in the class.

Concepts:

- Dry objects that are already at room temperature do not change temperature if they are moved rapidly.
- When water evaporates (becomes a gas) it has to take heat from somewhere.
- The effect of evaporating water on a surface is to cool it down by removing heat.
- Rapid movement cools wet things down by speeding the rate of evaporation.
- Controls are used in experiments to isolate effects before trying to examine them.

Objectives:

The students will be able to:
- State that evaporation results in cooling.
- State that proper use of controls makes interpreting results much easier.

General description of the experiment:

This activity is a direct follow-up of Activity 5-1, and offers a qualitative look at the phenomenon of evaporation. The two thermistors are wrapped in cotton balls, one of which is soaking wet. Both thermistors are than placed in front of a fan, or cooled by fanning with stiff paper. The discussion centers around the increased cooling effects that are observed, some of which are due solely to the moisture on the thermometer, and some of which are related to the combined effect of moisture and air motion.

Classroom lesson:

1. Go over the results of Activity 5-1 again. Emphasize that the temperature dropped only when the thermistor was wetted and then whirled through the air. Be sure everyone is familiar with the term 'cooling by evaporation.' The point of this experiment is to measure this quantitatively, not to introduce the idea.

2. Start **PLAYING WITH SCIENCE: Temperature** and select DO AN EXPERIMENT from the Main Menu. Set the Set-Up options as follows:

Range:	MAX	30°C	(90°F)
	MIN	20°C	(70°F)
Type of display:	Line		
Time:	6 minutes		
Number of thermistors:	2		

   One-Computer Classroom: Bring the class together, and while students watch, conduct the experiment as a demonstration. You can let one group fan the thermistors by using the extension cable to move it within reach of them. Students should complete their own copies of Activity Sheet 5-2.

   Multi-Computer Classroom: Each group should work on the experiment individually. Bring them together at the end to discuss their answer to the questions on Activity Sheet 5-2.

3. Following the directions on Activity Sheet 5-2, wrap the white and blue thermistors in dry cotton. Now press RETURN to start recording data. Collect data for 1 minute, giving the temperatures a chance to settle down. These temperatures will be the base temperatures (the first control).

4. Press RETURN to stop recording the data. Put the cotton ball on the end of the blue thermistor in the pan of room temperature water, letting it get soaking wet.

5. Hold both the white and blue thermistors in front of the fan and press RETURN to start recording the data again. Let the program continue to collect data for 5 more minutes. Stop by pressing RETURN when the timer on the bottom right of the screen says 6 minutes.

6. Switch to ANALYZE DATA. Using the graph, have students answer the questions on Activity Sheet 5-2.

7. Discuss with students why the graph for the blue thermistor shows such a distinct drop in temperature. The two controls in use during this experiment are the readings of room temperature at the beginning, which establishes a base temperature, and the white thermistor all the way through. Discuss the meaning of controls with students if they are old enough to understand the concept.

Getting the idea:

All the ideas mentioned in Activity 5-1 are also important here. If necessary, they can be repeated for emphasis. This activity adds an element of control to Activity 5-1, and for that reason is of interest.

Except on days with very high humidity (when lots of water is already present in the air as water vapor) air can naturally absorb water. In order to do this, the water must first be converted to the gas form of water, water vapor. The process to do that is called evaporation, and it uses energy to make the conversion. This energy must come from somewhere, and the cotton ball (and indirectly the thermistor) are likely sources. Thus, the thermistor registers a drop in temperature as the water is converted to water vapor.

Several variables control the rate of evaporation. An important one, but difficult to control in a classroom situation, is humidity. The greater the humidity in the air, the less room there is for more water vapor, and the lower the rate of evaporation. On very humid days, the temperature seems much higher than it is because your body cannot effectively sweat (lose heat through evaporation).

Another variable, and one studied in this experiment, is air movement. When the wind blows, more air passes a particular spot in a period of time. This increased air movement means that a wet object in a breeze is exposed to more dry air than one surrounded by still air. Thus the rate of evaporation increases, and there is a greater cooling effect.

Expanding the idea:

Have students look up and compare relative and absolute humidity. Most newspapers report relative humidity, and students can monitor it for a week or more as part of a unit on weather. Since temperature is an important component, it should be reported also.

A clay bottle can be used as natural thermos by wetting it on the outside and letting evaporation cool off the inside. Have students design an experiment, using **PLAYING WITH SCIENCE: Temperature** to monitor the amount of temperature change provided by such a natural material.

Alcohol has a higher rate of evaporation, and produces an even more pronounced cooling effect. Have students repeat the experiment, adding a third thermistor, this one wrapped in alcohol soaked cotton to observe the differences.

Activity Sheet 5-2
Learning about water

Question: Can we measure the cooling effect of evaporation?

Setting up the experiment:

Step 1) Start **PLAYING WITH SCIENCE: Temperature** and select DO AN EXPERIMENT from the Main Menu. Set the Set-Up options as follows:

Range:	MAX	30°C	(90°F)
	MIN	20°C	(70°F)
Type of display:	Line		
Time:	6 minutes		
Number of thermistors:	2		

Step 2) Select EXPERIMENT and press RETURN.

Making observations:

Step 3) Wrap the white and blue thermistors in dry cotton. Press RETURN to start recording data. Collect data for 1 minute. Press RETURN again to stop taking data. What does the graph look like?

_____

_____

_____

Step 4) What is the temperature of the white thermistor now? _____
What is the temperature of the blue thermistor now? _____

Step 5) Put the cotton ball on the end of the blue thermistor in a pan of room temperature water, letting it get soaking wet. You can squeeze the cotton a bit to make it stay on the thermistor.

Step 6) Hold both thermistors in front of a fan, or have one of your group fan the thermistors with a piece of paper. At the same time, press RETURN to start recording data again. Continue to collect data for 5 more minutes, fanning the thermistors the entire time. Stop collecting data by pressing RETURN when the timer on the bottom right of the screen says 6 minutes.

Sunburst Communications © 19 3

Thinking about the results:

Step 7) Switch to ANALYZE DATA.

Step 8) Use the *Zoom* option to make the graph easier to read. Print out a copy of it by using the *Print All* option. Attach the graph to this worksheet and use it to answer the following questions.

What happened to the temperature of the white thermistor? Did it change? By how much? _____

_____

What happened to the temperature of the blue thermistor? Did it change? By how much? _____

_____

What do you think is the difference between the blue and white thermistor in this experiment? _____

_____

When the cotton was wetted, what happened to the temperature?

_____

_____

Where did the water get the heat to become a vapor in this experiment?

_____

_____

_____

Write a brief definition of "rate of evaporation." _____

_____

_____

_____

_____

_____

_____

Things that don't change, or change only very slightly during an experiment are often called controls. The idea is to see the variation of something else, in comparison to the control. We used controls twice in this experiment. Can you guess when and what? _____

_____

_____

_____

_____

_____

_____

_____

Sunburst Communications © 1988

Classroom Lesson Plan 5-3
Learning about water

Question 5-3: What happens when soda water freezes?

Grade level: 1-5

Equipment needed:

- Sealable plastic or paper containers. Use a container with an air-tight seal. Good quality plastic ice cream containers, cottage cheese or cream cheese containers, or even empty plastic soda bottles will work.
- Enough cold soda to fill the container to overflowing. Soda or any other carbonated beverage will work very well. For a truly exciting effect, students can try freezing plastic bottles of soda that have never been opened.
- Copies of Activity Sheet 5-3 for each student in the class.

General description of the experiment:

This experiment is a qualitative investigation to confirm what the students should already know. If there are no facilities at school to make ice cubes, have students do this activity at home. It works just as well, and may even make for more interesting classroom discussion.

While adults 'know' that water expands when it freezes, most young people do not have practical experience with this phenomenon. This experiment asks them to freeze carbonated water under controlled conditions and observe the effects. Schedule this activity for a weekend by handing out the Activity Sheet on a Friday. This will insure that students have enough time to really let the soda freeze. Soda is recommended over regular tap water since the carbonation exaggerates the effects, making them much more noticeable. Plus, parents may be more willing to participate since they will not be as sure of the results as they might be if just plain water is used.

Classroom lesson:

1. Start the discussion by asking what your students already know about the behavior of water. A list of known characteristics can be placed on the blackboard, and copied into everyone's science notebook. Don't emphasize correct vocabulary now. It will come naturally out of the notes taken at home.

2. Hand out copies of Activity Sheet 5-3 to every student.

3. Go over the instructions with the students. Be sure that they understand the importance of filling the container as completely as possible and of obtaining an air tight seal. Remind them not to let the cold soda water sit around before filling and sealing the container.

4. Students are expected to observe what happens and to try to describe it as completely as possible. Since this is an at-home activity, getting parents to help is not only expected, but desirable. If scheduling permits, try to schedule this over a weekend to give ample time for discussion and observation to occur.

5. As students come into the room on Monday morning, have some of them copy their before and after sketches on the blackboard.

6. Since water expands when frozen (and since the carbonated air is forced out of the soda water also putting a great deal of pressure on the lid), everyone should have at least observed that the containers became distorted in shape. In most cases, in fact, the lid should have been popped off. Did any containers break? Did students expect them to break? Why? What would students change if they wanted to be sure that the containers would break?

7. Vocabulary to discuss includes: Freezing, Expansion, Ice, Solid, and Freezing and Melting Point.

8. With older students, you may want to discuss the difference between soda water and plain water, emphasizing the fact that ice is actually fairly pure water. In effect, freezing is a form of water purification. Would students expect to get the same results if they had used plain water instead? What about trying the experiment with other liquids? If time permits, students might want to repeat the experiment with a different liquid, such as corn oil or alcohol. Assign different liquids to different students to be sure that a variety of different effects are seen.

Getting the idea:

Be sure students observed that water expands when it freezes. The amount of time required may be surprising. Older students may want to refine this experiment to take the time into account.

Proper vocabulary is quite important, and is best introduced after students have some experience with the phenomenon under study. In this case, depending on the ages of your students, use words like freezing and melting freely. With older students, you can introduce the concept of physical change, if desired. Melting point and freezing point are also appropriate terms.

By using soda water instead of tap water, we guaranteed that there would be air trapped in the water. When the water froze, the air (as well as most other physical impurities, such as dirt) is forced out. This increase in air pressure popped the lid. Had the container been made of glass with a screw top, the glass would likely have burst. If you try the experiment with a full bottle of soda in a 2 liter bottle, the sides are very likely to split under the increased pressure.

Expanding the idea:

This experiment is an introduction to the further study of freezing point in Activity 5-4. If your students are interested in other home study projects, ask them to experiment with different sized containers or different liquids. Caution students to stay away from using glass containers.

If you would like to prove dramatically that water expands when frozen, but without using soda water to amplify the effects, here is a good experiment to do in class or have students do at home. Have students fill a tall paper cup with water and put it uncovered in the freezer overnight. When the water is frozen, take the cup out, and on the inside of the cup, using a water-proof colored marker, mark the level of the frozen water. Now, every five minutes, they should look at the cup, and again mark the new level of the water on the inside of the cup. As the ice melts, the volume will go down, dramatically illustrating that the water did indeed expand when it froze.

A quick experiment to illustrate the fact that water will expel foreign materials when it freezes can be done by first making a soup of water, dirt, and salt. Ask students if they would like to drink it. Put the soup into ice cube trays and freeze it. When it has frozen solid, remove the ice cubes from the trays, and rinse them off under the tap. Put the ice cubes into a separate bowl and let them melt. Do they look like the dirty soup? What happened to the materials that were in the water when it froze? Where are they now? Is the water clean enough to drink? If not, freeze the water again and repeat the procedure. Eventually, you will end up with fairly clean water. Ask students why this method wouldn't be a good method to use commercially.

Activity Sheet 5-3
Learning about water

Question: What happens when soda water freezes?

Setting up the experiment:

Step 1) Get a plastic or paper container with an air-tight lid. Ice cream containers, cottage cheese containers, or soda bottles will work well.

Step 2) Fill the container completely full of a cold carbonated beverage such as soda. Tightly put the lid back in place.

Step 3) Make a sketch of the container below, in the space provided.

Step 4) Carefully, without spilling any of the soda water, place the container in the freezer.

Step 5) Leave the cup in the freezer at least overnight. Depending on the size of the cup used and the temperature of the freezer, it may be necessary to wait for two days before the liquid is completely frozen.

Step 6) Take the container out of the freezer and put it in the sink. Again make a quick sketch of the container. Answer the questions on the next page while you look at the container very carefully.

Making observations:

Sketch before freezing

Sketch after freezing

Sunburst Communications © 1988

Thinking about the results:

Does the soda water look the same as it did before it was frozen?

_____
_____

How has it changed? _____
_____
_____

Has the container changed? _____
How has it changed? _____
_____
_____
_____

Why do you think the change happened? _____
_____
_____
_____
_____

What do you think the variables are in this experiment?

_____
_____
_____

The bubbles are the biggest difference between soda water and regular water as far as this experiment is concerned. How do you think the bubbles affected the results? _____
_____
_____
_____

Have you ever shaken up a warm can of soda and had all the drink shoot out of the can at you? What do you think happened? Would the same thing happen if you shook a cold can of soda? Does temperature affect the bubbles? _____
_____
_____
_____

What would happen if you tried the experiment again, using cold tap water? Why not try it and see for yourself by freezing one container full of water at the same time you freeze one container full of soda water!

Sunburst Communications © 1 8

Classroom Lesson Plan 5-4
Learning about water

Question 5-4: Why does it take so long for large blocks of ice to melt?

Grade level: 4-7

Equipment needed:

- **PLAYING WITH SCIENCE: Temperature** with the white and blue thermistors.
- One fairly wide test tube for every group that will be doing this experiment.
- Two wide mouth jars, large enough to hold the test tube, for each group.
- Hot and cold water in pitchers, enough to fill all the jars.
- A box of moth flakes. Melting this material in the test tubes ruins them for anything else, so don't use your best ones. Fortunately, the material in the test tubes is reusable, so plan on storing it there for next year.
- Enough squares of heavy duty plastic to cover all of the blue thermistors.
- Copies of Activity Sheet 5-4 for each student in the class.

Concepts:

- Heat is released as liquids form solids.
- Some liquids maintain a constant temperature while they become solids. This is true of both water and moth flakes, for example.
- This constant temperature during freezing is called the freezing point.
- Freezing point is a characteristic property of many materials.

Objectives:

The students will be able to:

- State that liquids become solids when they cool sufficiently.
- State that heat is released as solids are formed.
- Define freezing point as the temperature at which a liquid becomes a solid, and recognize that that temperature is constant during the entire freezing period for many materials.
- Recognize a standard freezing curve graph when shown one.
- State that freezing point is a characteristic property of some materials.

General description of the experiment:

Moth flakes, a common material that becomes a solid at a temperature slightly above room temperature, are used to explore what happens when liquids become solids. The moth flakes are melted by being placed in a test tube which is then placed in a jar of very hot water. After the moth flakes become liquid, the test tube is transferred to a jar filled with very cold water, and the temperature is monitored. The thermistor will register a steady reduction in temperature, until the moth flakes start to harden. At that point the temperature remains constant until all the flakes have solidified. Then the temperature starts to drop again.

Classroom lesson:

1. Fill the test tubes one-third to one-half full of moth flakes and place them in hot water until all the flakes have melted. Allow them time to return to room temperature before doing the experiment. Wrap all the blue thermistors you will be using carefully in several layers of plastic. Since you will need a good quality plastic, cut large squares out of heavy duty plastic bags, such as clear freezer bags.

2. Start the class discussion by asking which takes longer to melt, a large pile of snow or a small pile of snow, a large block of ice or a small block of ice. Have students generate hypotheses to answer this question, and list them on the board or in their notebooks. After the experiment is finished, go back to these lists and see if it is possible to eliminate some of the hypotheses based on the information learned.

3. Start **PLAYING WITH SCIENCE: Temperature** and select DO AN EXPERIMENT from the Main Menu. Set the Set-Up options as follows:

Range:	MAX	100°C	(212°F)
	MIN	0°C	(32°F)
Type of display:	Line		
Time:	25 minutes		
Number of thermistors:	2		

   One-Computer Classroom: While it is possible to bring the class together and have the students watch while you conduct the experiment as a demonstration, in this case it is not suggested. The crystal formation, which is very beautiful and an important part of the experiment, will not be seen by most of the students. If you have only one computer, you can have most of the groups do the experiment with standard thermometers, reading them every 5 minutes or so, and drawing their own graphs. The group that uses the computer can then compare their more detailed graph to those drawn by the rest of the class. Alternatively, you can set up the experiment in one corner of the room and let the students do it in rotation. In any case, students should complete their own copies of Activity Sheet 5-4.

   Multi-Computer Classroom: Each group should work on the experiment individually. Bring them together at the end to discuss their answer to the questions on Activity Sheet 5-4.

4. Carefully fill one of each set of jars about half-full of very hot water. Have students place the test tubes containing the moth flakes in these jars and watch them melt. They should answer Questions 2 and 3 on Activity Sheet 5-4.

5. When the moth flakes have completely become liquid, put the blue thermistor (after it has been securely covered in plastic) in the test tube. The thermistor should be suspended in the hot liquid, not touching the sides of the test tube.

6. Fill the other jar in each set with cold water. The test tube with the white thermistor should be placed inside this jar.

7. Students should now press RETURN to start collecting data. As quickly as possible, they should place the test tube, carefully holding the thermistor suspended in the liquid, into the jar containing cold water. Except for stirring with the blue thermistor from time to time, the entire experiment should now be left to sit while students answer the questions in Steps 8, 9, 10, and 11 on Activity Sheet 5-4.

8. The program will stop taking data after 25 minutes. By that time, the moth flakes should have completely solidified and the temperature begun to drop again. Have the students save their data. They may not have time to do the experiment, finish the analysis and answer the rest of the questions in one class period.

9. *Clean up:* Have students place the test tubes back in hot water baths and let the moth flakes become liquid again. Once this happens, the thermistors can be removed by gently pulling them from the liquid and removing the plastic wrapping.

10. At the start of the next class period, have students use ANALYZE DATA and retrieve their data. They can continue using the Activity Sheet, answering questions as they go.

11. In this experiment, students determine the freezing point of moth flakes. Getting them to recognize that the plateau (flat section) in the cooling curve occurs only in materials with clearly defined freezing points is a difficult concept. It is really critical only that they recognize that moth flakes are a model for water, which behaves in a very similar manner. Emphasize why water would not have been a good choice for an experiment like this. Also discuss what would happen to the graph if the amount of moth flakes had been larger. Student graphs can be compared, since the amount of material in each test tube is bound to be quite different. Freezing temperature is a characteristic of the material, freezing time depends on the amount of material involved.

Getting the idea:

The graphs should all show two clearly different lines. The temperature of the cold water bath should increase slowly as the heat from the liquid moth flakes is conducted into the cold water. As the moth flakes start to solidify, they will gradually form crystals. Be sure to point out the formation of the crystals as evidence that the liquid is starting to become a solid. During this time, the temperature of the moth flakes, which was slowly descending, stops changing and becomes fairly constant. Any variation in this temperature can be related to insufficient stirring. If the moth flakes are not stirred, the flakes near the thermistor will be come a solid before the rest of the mass, and the plateau will be too small to see clearly. At the same time, the temperature of the cold water bath will continue to increase. This is important to point out, since this gradual increase is the only indication that heat is still given off by the moth flakes, even though the temperature is not changing.

Post the graphs so that students can see that the temperature of freezing is the same in all the experiments, within the error of the thermistors. What will change is the amount of time required to freeze the flakes. The more material, the longer it took to freeze them, a difference that can clearly be seen by looking at the length of the flat section of the graph.

One important point that is not demonstrated by this experiment but is critical to the understanding of phase change is that freezing point (the temperature at which a material goes from a liquid to a solid) and melting point (the temperature at which a material goes from a solid to a liquid) are the same. The reason for not doing the experiment the other way is the difficulty of stirring a solid. This means that a small amount of material around the thermistor can melt, and then continue to heat up since it is somewhat isolated from the bulk of the material. The melting point plateau, therefore is much less distinct.

The distinction between characteristics of the material (such as freezing, melting, or boiling point) and characteristics of the quantity of material tested (such as time to freeze or time to boil) is critical to predicting how things will behave.

Expanding the idea:

Have students look up the freezing and boiling points of some common materials in a book of physical facts. The encyclopedia will give these under the names of the materials themselves. Some materials do not have specific freezing points, for example candle wax will gradually solidify, never forming a plateau where the temperature remains constant as the material freezes. Other materials, such as wood, burn before they melt, and thus cannot be considered to have melting points. Reference materials on freezing point and boiling point can be found in many science textbooks.

Older students may wish to do a similar experiment with boiling water. Have them design it and test it if time permits.

Activity Sheet 5-4
Learning about water

Question: Why does it take so long for large blocks of ice to melt?

Setting up the experiment:

Step 1) For this experiment you will need two thermistors. The blue one will have to be securely covered with plastic. If your teacher has not already done so, take several large squares of heavy duty plastic and securely wrap them around the thermistor and up the sides of the cable. For best results, the plastic should extend at least 5 inches high. It can be held in place by masking tape.

Step 2) Get a test tube filled with solid moth flakes. Describe the appearance of the material in the test tube in the space below.

_____
_____
_____

Step 3) Obtain a jar filled with hot water and one filled with cold water. Place the test tube in the jar filled with hot water and wait until the moth flakes are completely melted. If necessary, add additional hot water after several minutes to speed along the process. Describe the appearance of the liquid moth flakes below.

_____
_____
_____
_____

Step 4) After the moth flakes have completely melted, carefully place the blue thermistor (after it has been wrapped in plastic) inside the test tube. Be sure that the liquid does not go up over the end of the plastic wrap. Place the white thermistor in the cold water bath.

Step 5) Start **PLAYING WITH SCIENCE: Temperature** and select DO AN EXPERIMENT from the Main Menu. Set the Set-Up options as follows:

Range:	MAX	100°C	(212°F)
	MIN	0°C	(32°F)
Type of display:	Line		
Time:	25 minutes		
Number of thermistors:	2		

Step 6) Select EXPERIMENT and press RETURN.

Step 7) If you have the white thermistor in the cold water bath, and the blue thermistor safely in the test tube, you can carefully place the test tube in the cold water bath, and then press RETURN to start taking data.

Sunburst Communications © 1988

Making observations:

Step 8) What is happening to the temperature of the blue thermistor, the one in the test tube of moth flakes. Is it showing a decrease in temperature? Where is the heat going? _____

_____

_____

_____

Step 9) What is happening to the temperature of the white thermistor? Is it gradually going up? Where is the heat coming from to make the cold water bath get warmer? _____

_____

_____

_____

Step 10) At some temperature, the blue thermistor will stop showing a change. Watch the graph carefully so that you can see the beginning of the plateau. What is the temperature reading at that point? _____

What is the time? _____

What does the liquid in the test tube start to look like as the temperature of the liquid stops changing? _____

_____

_____

_____

What do you think is happening? _____

_____

_____

_____

_____

Step 11) Gently stir the liquid in the test tube with the blue thermistor. You will have to do this every few minutes to keep the crystals from forming around the thermistor before they form in the rest of the liquid. Keep watching the test tube and record any changes you notice, the time you noticed them, and the temperature at that moment on the chart below.

Time	Temperature	Change noted

Sunburst Communications © 1 38

Step 12) When the program stops taking measurements, save the data. Type a file name that you will remember. Record that name here and the label on the data disk you used: _____

Step 13) Now follow your teacher's directions for removing the blue thermistors from the solid moth flakes in the test tube and for proper disposal of the test tubes. DO NOT ATTEMPT TO PULL OUT THE THERMISTOR UNTIL THE MOTH FLAKES ARE COMPLETELY LIQUID AGAIN.

Thinking about the results:

Step 14) During the next class period, use **PLAYING WITH SCIENCE: Temperature** and choose ANALYZE DATA from the Main Menu. Load the data which you saved previously.

Step 15) Look closely at the graph. Can you tell which thermistor was in the cold water bath and which one was in the test tube full of moth flakes?

_____

How do you know? _____

_____

Step 16) Use *Select Thermistors* to look at the temperature readings of only the blue thermistor. Then use *Zoom* to enlarge the graph. Capture the entire length of the plateau.

The plateau represents what was happening to the temperature of the liquid while it was changing to a solid. The almost constant temperature can be considered the freezing temperature of moth flakes. What is it?

_____

How long did it take for the moth flakes to solidify? _____

_____

Step 17) Use *Print All* to get a copy of your graph. Label the following points of the graph according to your notes, and attach the graph to your report.

- Starting temperature of the hot liquid moth flakes.
- Starting temperature of the cold water bath.
- Temperature where crystals started to appear.
- Temperature at which no more crystal growth seemed to occur.
- Freezing point of moth flakes.
- Coldest temperature of the moth flakes.

Step 18) Compare your graph with those of your classmates.

Did every graph have a flat section (a plateau)?

_____

Were the temperatures of the flat sections similar or very different from graph to graph? _____

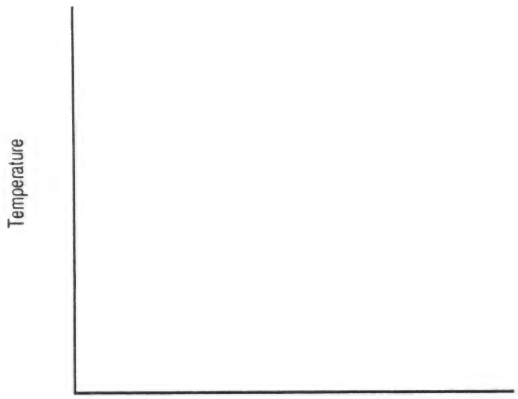
Were the lengths of the flat sections (the plateaus) similar or very different from graph to graph? _____

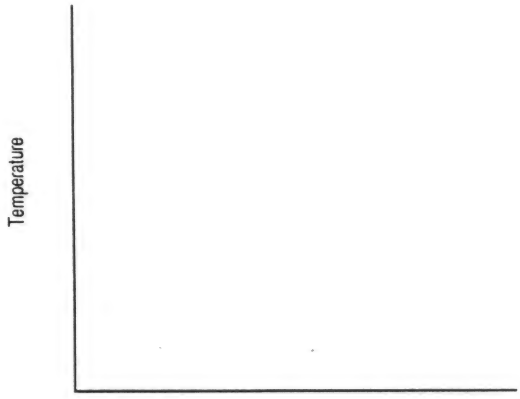
Sunburst Communications © 1988

Step 19) Sketch two graphs below. One on them should show the cooling curve of a small mass of moth flakes and the other a large mass. What are the differences? _____

_____

_____





Step 20) A characteristic property is a property that does not depend on the quantity of the material, just on the kind of material tested. In other words, properties that are the same whether the sample tested is very large or very small, are called characteristic properties of that material.

Based on this experiment, is the freezing point of moth flakes a characteristic property? _____

_____

Does the amount of time required to make liquid moth flakes become a solid a characteristic property? _____

_____

Does the amount of heat energy required to make solid moth flakes a liquid depend only on the fact that we are melting moth flakes alone, or is the amount of moth flakes to be melted important as well?

_____

_____

_____

Can you name some other properties of moth flakes that might be characteristic properties? _____

_____

_____

_____

_____

_____

_____

Sunburst Communications © 88

Classroom Lesson Plan 5-5
Learning about water

Question 5-5: Can you boil water in a paper bag?

Grade level: 4-7

Equipment needed:

- **PLAYING WITH SCIENCE: Temperature** with the white thermistor.
- A candle or Bunsen burner.
- Paper lunch bags
- One pair of tongs.
- Copies of Activity Sheet 5-5 for every member of the class.

Concepts:

- Heat is absorbed as liquids form gases.
- Water maintains a constant temperature while becoming a gas.
- This constant temperature during boiling is called the boiling point.
- Boiling point is a characteristic property of many materials.
- Paper will not burn unless a critical temperature is obtained. We call this critical temperature the kindling point.

Objectives:

The students will be able to:

- State that water become water vapor (a gas) when heated sufficiently.
- State that heat is absorbed as gases are formed.
- Define boiling point as the temperature at which a liquid becomes a gas, and recognize that that temperature is constant during the entire boiling period for many materials.
- Recognize that a standard boiling curve graph is similar to a standard freezing curve.
- State that boiling point is a characteristic property of some materials.

General description of the experiment:

When asked to explain how is it possible to boil water in a paper bag, most people are stumped. In this demonstration, under controlled and measured conditions, the boiling point of water is found, using a paper bag to hold the water. And what keeps the bag from burning? The heat removed by the water in order to boil is so great that the burning temperature of the paper cannot be reached until after all the water has turned to vapor.

Classroom lesson

1. Ask students what they would do if they got stuck out in the woods with no pots, and needed to boil water. After encouraging their suggestions, ask if they think it would be possible to boil water in a paper bag. Again, encourage their opinions, both positive and negative. When discussion has stopped, say that we will now try to determine the truth of their statements. Take a piece of a paper bag and gripping it in a pair of tongs, hold it over a candle flame. Start counting. The paper will quickly catch fire and burn. We often refer to the temperature required to burn paper as the *kindling temperature*. Now wet another piece of paper and hold it over the fire, again counting. This time it will take longer for the paper to catch fire. Ask your students to explain the difference. Make a list of the various possibilities. Now begin the demonstration. Be sure to use a large monitor so that everyone will be able to see the graph..

2. Start **PLAYING WITH SCIENCE: Temperature** and select DO AN EXPERIMENT from the Main Menu. Set the Set-Up options as follows:

Range:	MAX	120°C	(240°F)
	MIN	80°C	(170°F)
Type of display:	Line		
Time:	10 minutes		
Number of thermistors:	1		

3. Since you will be working with open flames in the classroom, it is essential that you go over fire safety rules and regulations. You should have a fire extinguisher handy. Caution students against being too close to the demonstration site. If you are not comfortable with the safety situation, do not do this demonstration.

4. Put a small amount of water in a paper bag (no more than 2.5 cm or 1 inch deep). Place the white thermistor inside the paper bag as well, being sure that it does not come in contact with the paper in any way. Use tape and paper clips if necessary to support it.

5. Start recording data and then using tongs, hold the bag over the flame. The water inside will start to boil, as evidenced by the steam that will escape from the top of the bag. As long as the flame is in contact only with bag surface that is also in contact with the water, it will not burn. Be sure the boiling point plateau is visible before stopping the experiment. It is not necessary, nor advisable, to try and boil the bag dry.

6. The program will stop taking data after 10 minutes. By that time, the water should have been boiling for several minutes, at a constant temperature of about 100°C (212°F). Save the data. There may not be enough time to do the experiment, finish the analysis and answer the rest of the questions in one class period.

7. If you have more than one computer available, use the *Copy Files* option in the UTILITIES section of **PLAYING WITH SCIENCE: Temperature** to make multiple copies of this file. In this manner, every group will be able to do the analysis independently.

8. At the start of the next class period, have students select ANALYZE DATA and retrieve the file, or do it for them on the large monitor. They can continue using the Activity Sheet, answering the questions as they go.

9. There are two main concepts to be stressed in discussion. The plateau of boiling water, so similar to the plateau observed in freezing moth flakes, allows us to believe that this shape will be common to many different materials. In fact, it is a typical phase change curve. If your students are able to appreciate this abstraction, mention it. If not, stress that the graph shows us that the water has to absorb heat constantly to become a gas. Since the temperature stops changing even though heat continues to be added to the water, the extra heat must be going to make the phase change happen.

   The second concept has to do with the bag not burning. Very few things burn spontaneously. Most require reaching a critical temperature first. The critical temperature for paper is much higher than that of water, and thus it boils before the paper burns. Once the water starts to boil, it uses all the heat to power the phase change, leaving none to continue heating the paper.

Getting the idea:

The graph should show a line that gradually increases in temperature and then flattens out when the water comes to a boil. If you have calibrated the thermistors, this flat portion should be at 100°C (212°F).

Post the graph so that students can see that the temperature of boiling is a constant. Students may be able to conclude that the more material, the longer it takes to boil, and the longer it will remain at the boiling point. Since you should not permit the bag to boil dry (it will flame easily then and become dangerous), the length of time at the plateau is essentially meaningless.

The distinction between the characteristic properties of the material (such as freezing, melting, or boiling point) and characteristics of the quantity of material tested (such as time to freeze or time to boil) is critical to predicting how things will behave.

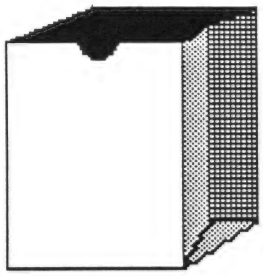
One interesting idea that comes out of this experiment is that of kindling point. Heat alone will not cause paper to burn; enough heat is required to reach the kindling temperature. After that, the heat from the fire is sufficient to get more paper to burn, suppling more heat and thus keeping the fire going. Starting a fire can be difficult if the wood is wet, since the water must first be evaporated (turned into water vapor) before the kindling temperature can be reached. We commonly use matches and lighter fluid to help us get paper (and wood) up to the kindling point. Both matches and lighter fluid ignite at lower temperatures, and supply heat that can be used to get the wood hot enough to burn. Sometimes, we put paper underneath wood for the same reason. We need to supply enough heat for enough time to get the wood started burning.

Expanding the idea:

Have students look up the freezing and boiling points of some common materials in a book of physical facts. The encyclopedia will give these under the names of the materials themselves. Some materials do not have specific freezing points. For example, candle wax will gradually solidify, never forming a plateau where the temperature remains constant as the material freezes. Other materials, such as wood, burn before they melt, and thus cannot be considered to have melting points. Reference material on freezing point and boiling point can be found in many science textbooks.

Activity Sheet 5-5
Learning about water

Question: Can you boil water in a paper bag?



Making observations:

Step 1) Record any changes, and the time and temperature at which they occurred, on the chart below.

Time	*Temperature*	*Change noted*

Step 2) What is happening to the temperature of the thermistor? Is it showing an increase in temperature? Where is the heat it is gaining coming from? _____

_____

Step 3) At some temperature, the thermistor will stop showing a temperature change. Watch the graph carefully so that you can see the beginning of the plateau. What is the temperature reading at that point?

_____

What is the time? _____

What is coming out of the top of the paper bag when the temperature levels off? _____

_____

If the heat coming from the candle is not going to heat up the water, where is it going? _____

_____

_____

_____

_____

Sunburst Communications © 1988

Thinking about the results:

Step 4) During the next class period, start **PLAYING WITH SCIENCE: Temperature** and choose ANALYZE DATA from the Main Menu. Retrieve the data.

Step 5) Use the *Zoom* option to enlarge the graph. Enlarge the section that shows the curve leveling off and becoming a plateau.

The plateau represents what was happening to the temperature of the liquid while it was changing to a gas. The almost constant temperature can be considered the boiling temperature of water. What is this temperature? _____

Step 6) Use *Print All* to get a copy of the graph. Label the following points of the graph according to your notes, and attach the graph to your report.

- Starting temperature of the hot water
- Boiling point of water
- Constant temperature while the water becomes water vapor (undergoes a phase change)

Step 7) Compare your graph with those of your classmates.

Did every graph have a flat section (a plateau)?

_____

Were the temperatures of the flat sections similar to or very different from graph to graph? _____

_____

Were the lengths of the flat sections (the plateaus) similar or very different from graph to graph? _____

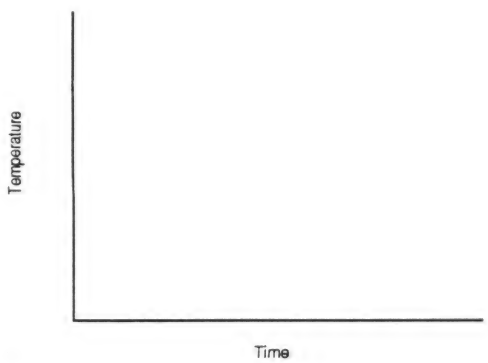
_____

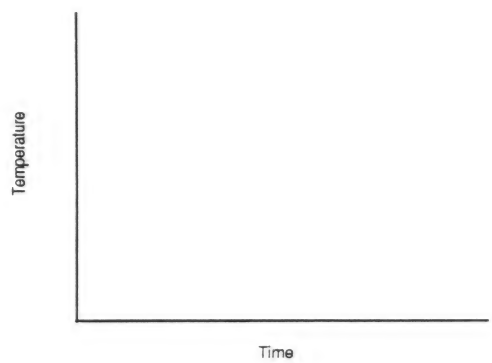
Step 8) Sketch two graphs below. One on them should show the boiling curve of a small mass of water and the other a large mass. What should be the differences? _____

_____

_____

_____





Sunburst Communications © 1988

Step 9) A characteristic property of a material is a property that does not depend on the quantity of the material, just on the kind of material tested. In other words, characteristics that are the same whether the sample tested is very large or very small, are called characteristic properties of that material.

Based on this experiment, is the boiling point of water a characteristic property? _____

Is the amount of time required to make water become a gas a characteristic property? _____

_____

_____

_____

Can you name some other properties of water that might be characteristic properties? _____

_____

_____

_____

_____

_____

Step 10) Why didn't the paper bag burn? If the heat did not go to raise the temperature of the bag to the kindling point, where did it go?

_____

_____

_____

_____

Sunburst Communications © 1988

Classroom Lesson Plan 5-6
Learning about water

Question 5-6: Why is the bottom of the ocean so cold?

Grade level: 4-7

Equipment needed:

- **PLAYING WITH SCIENCE: Temperature** with all three thermistors.
- A large, tall container for water.
- Pitchers of hot and very cold water.
- Red food coloring or water-soluble dye.

Concepts:

- Cold water is denser than warm water.
- Cold, dense water sinks and pushes up warm, less dense water.
- Ocean water temperature decreases with depth.
- Ocean water is very cold at extreme depths.
- Convection currents exist between hot and cold areas of water.

Objectives:

The students will be able to:
- Predict circulation caused by the temperature differences.
- Predict where water will be the coldest in a large lake.

General description of the experiment:

Thermistors are taped vertically up the inside of a large container of water. Half of the container is filled with hot water, and then colored cold water is slowly poured in on top. The different densities will cause the cold water to sink (the temperature of the lower thermistor will go down), and the hot water to rise (warming up the top and middle thermistors). In addition to this abstract indication of circulation, the red color will be seen to flow down into the bottom of the container, pushing the clear hot water upwards.

As time passes, since the container is not as large as the ocean, the waters will mix, and the temperatures will gradually approach each other. However, with really large containers and thermistors calibrated for accuracy, a slight difference will still be noticeable even after mixing has occurred. If the container is placed so that a bright light shines on the top, the temperature difference will be maintained, even though the circulation has stopped since the less dense (lighter) water is on top.

Classroom lesson:

1. Start the discussion by asking students what they think the temperature of ocean water is. Obviously, the temperature depends on where you are, and students should quickly realize that the farther north you go the colder the water gets. Some may also know that the deeper you go the colder the water gets. Even in swimming pools, if you are one of the first in, the water is warmer on the top and colder on the bottom.

2. Describe the experiment to your students, explaining that you will be taking the temperature of the water in a large container. Ask them to predict the shape of the graph. After the experiment is finished, compare their hypothesized graph with that of the actual experiment. Were they mostly correct? Where did unexpected things happen? What was the reason behind asking them to predict the result before the experiment? Did it make understanding the results easier or harder?

3. Start **PLAYING WITH SCIENCE: Temperature** and select DO AN EXPERIMENT from the Main Menu. Set the Set-Up options as follows:

Range:	MAX	100°C	(212°F)
	MIN	0°C	(32°F)
Type of display:	Digital		
Time:	10 minutes		
Number of thermistors:	3		

   This experiment makes an excellent demonstration. Have each member of the class answer the questions on Activity Sheet 5-5 individually, if desired.

4. Use a very large water container, clear if possible, but translucent will do if it is the only thing available. Height is important, so use the tallest cylinder available. If you must use an opaque container, don't put in the red dye, since the effect will be lost on your students. Using plenty of tape in a criss-cross pattern, fasten the white thermistor as close to the bottom as possible without touching. Tape the blue thermistor in the center and the green thermistor near the top, but at least 5 cm (2 inches) below the expected water line.

5. Press RETURN once to start taking data. Wait one minute. The temperatures showing on the thermistors at this point are room temperature readings.

6. While the program is still recording temperature, fill the container with hot water. Stop about 5 cm or 2 inches above the green thermistor. Leave this to sit while you remove the ice from the cold water, and add red food coloring. Stir it around.

7. Very slowly and very smoothly, add a small amount of the cold red water to the container. Allow the thermistors to continue taking data as the red cold water sinks to the bottom, forcing the hot water up. Point out the presence of the convection current. It should be possible to see red streamers moving as the current is formed.

8. Allow the temperatures to stabilize. Which thermistor shows the lowest temperature? The highest? Have students offer suggestions to explain the observed measurements. You can continue to add small amounts of cold water from time to time. Is the same effect observed?

9. Have students describe what happened to the cold and hot water, using the graphs as well as the physical look of the water container to explain their results. Have them explain which parts of the graph indicate which part of the experiment. In particular they should be able to explain why the temperature of the white thermistor shot up so quickly, and then gradually cooled, while the green thermistor actually did almost the opposite thing. What do they think the blue thermistor was measuring? It may very well show the highest temperature of all since it is less effected by the addition of the cold water at the surface, nor is it effected by the sinking of the cold water to the bottom.

10. Have students try to answer the following questions: In the ocean, what are the sources of hot and cold water? As the cold water from the poles sink, where can it go? In our hemisphere, the cold water currents flow south, and in doing so, help force the warm waters from the Caribbean (on the Atlantic side) to flow north. This northward flow is called the Gulf Stream.

11. Do convection currents also form when cold and warm air meet? In **Expanding the idea** a quick experiment is described to prove that hot air, just like warm water, will rise, and therefore the same forces are at work in the air as in the sea. Winds are caused by variations in pressure, which are in turn caused by variations in air temperature.

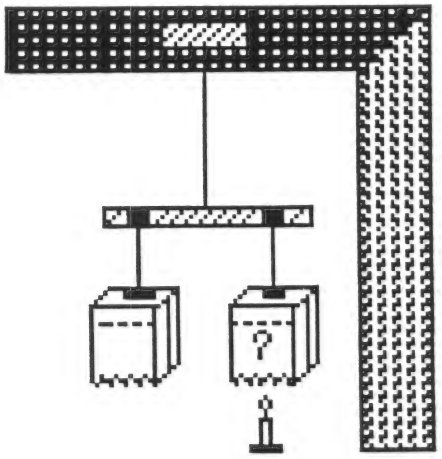
Getting the idea:

Convection currents in the water make the oceans a good place to live. Minerals are brought up from the bottom by the cold water, and act as nutrients for both fish and plant life. Warm water flowing northward warms our coast, keeps our climate mild, and is a critical influence on our weather.

Expanding the idea:

Students can look up almost an infinite number of different topics in this area. Starting places might include Oceans, particularly the Atlantic and Pacific. Currents that occur on the east coast include the Gulf Stream, and the Labrador Current. On the west coast, students might look up the Japanese and Peru Currents. Just recently the Peru Current (a cold water stream) changed direction dramatically with some interesting effects on fishing along the west coast. Older students might want to research this fairly current event that relates politics, economics and science.

If you want to expand this idea of warmer vs. colder water to the related idea of warmer vs. colder air, the following is a very convincing demonstration. You will need lots of string, a wooden yardstick or meter stick, two paper lunch bags, a candle and matches. Tie a piece of string to the center of the meter stick, and hang it from the ceiling of the classroom. Attach the paper bags, open ends down, to either end of the meter stick so the whole set-up balances. Now, explain to the students that there is air inside the paper bags, and that all of it is at the same temperature (room temperature). Ask them to predict what will happen if you filled one of the bags with hot air. Would the set-up still balance? Now, have someone hold on to the stick while you light the candle and hold it under one paper bag. After a minute, take the candle away and release the stick. Does it still balance? Which side is lighter? Why?



Classroom Lesson Plan 5-7
Learning about water

Question 5-7: What happens when we "salt the water?"

Grade level: 3-7

Equipment needed:

- **PLAYING WITH SCIENCE: Temperature** with the white and blue thermistors.
- A box of salt and a bag of sugar.
- Two cups of room temperature water for every group that will be doing the experiment.
- Copies of Activity Sheet 5-7 for every student.
- Optional magnifying glasses for looking closely at the salt and sugar.

Concepts:

- Salt and sugar both dissolve in water and look very similar, but they have very different characteristics if one looks closely.
- Heat is absorbed when salt is dissolved in water.
- Heat is not absorbed when sugar is dissolved in water.
- Salt lowers the freezing point of water.

Objectives:

The students will be able to:
- List several different ways that salt and sugar differ from each other.
- Give reasons for putting salt on icy streets in the winter time.

General description of the experiment:

Students do this experiment in two parts. During the classroom session, students use the computer to observe the depression of temperature that dissolving salt in water produces. This is contrasted to the effect of dissolving sugar, where no temperature change is observed. Students are then asked to go home and use salt to melt ice sufficiently to get a string stuck to the surface. This demonstrates salt's depression of the freezing point of water.

Classroom lesson:

1. Put small amounts of sugar and salt on labeled paper plates or in paper cups that can be passed around the room. As this is being done, have students fill in the top of Activity Sheet 5-7 with as many characteristics of salt and sugar as they possibly can. If magnifying glasses are available, use these as well. After a few minutes, have everyone help list these characteristics on the board for all to see. Explain that doing this experiment will show them one more difference that they might have never noticed before.

2. Start **PLAYING WITH SCIENCE: Temperature** and select DO AN EXPERIMENT from the Main Menu. Set the Set-Up options as follows:

Range:	MAX	35°C	(95°F)
	MIN	20°C	(70°F)
Type of display:	Line		
Time:	5 minutes		
Number of thermistors:	2		

   One-Computer Classroom: This experiment works very well as a classroom demonstration. Simply gather everyone around one computer, preferably hooked to a large monitor, and follow the directions on Activity Sheet 5-7. Students should fill in their own copies of the Activity Sheet.

   Multi-Computer Classroom: Each group should work on the experiment individually. Bring them together at the end to discuss their answers to the questions on Activity Sheet 5-7.

3. Have students label their cups, one SUGAR and the other SALT. Put the white thermistor in the cup labeled SALT and the blue thermistor in the cup labeled SUGAR. Press RETURN to start taking data.

4. Student should wait one minute while the temperature of the water stabilizes, and then stop taking data. Use the *Graph* option to change the MAX and MIN temperatures to no more than 2°C (4°F) above and below the water temperature. Press RETURN to start taking data again.

5. Add several tablespoons of salt to one cup. Stir carefully, then wait. What is happening to the temperature of the water in the cup? Add the same amount of sugar to the other cup. Did the same thing happen in that cup?

6. When the computer stops taking data, have everyone switch to ANALYZE DATA and use *Zoom* to answer the questions on Activity Sheet 5-7.

7. Be sure that students see that salt and sugar, despite their similarity in appearance, are really very different materials. Update the chart of differences appropriately. Since salt has a very obvious effect on water, students will be well prepared for the at-home experiment described at the bottom part of the Activity Sheet. Remind students to follow up the experiment by doing this activity. The next morning, ask what happened, and have students describe the results. Were anyone's parents surprised?

8. If you live in a winter climate, now is a good time to discuss the advantages and disadvantages of salting the roads. Why wouldn't sugar be a good substance to use? Sometimes people use sand or dirt on roads. What effect would these have on the ice?

Getting the idea:

Salt is an ionic compound, and when it dissolves in water, it breaks apart, forming ions. It requires energy to break salt apart into ions, and heat is a good source of this energy. Therefore, the salt molecules take heat from the water and turn it into the energy they need. Sugar, on the other hand, is not ionic, and simply slips into the spaces between the water molecules, forming hydrogen bonds. Little heat energy is required to do this, and the temperature stays fairly constant. These are characteristic properties of the salt water and sugar water mixtures.

In the at-home experiment, placing salt on the ice cube causes the freezing point of the water, at that one spot, to be depressed. Thus a small puddle forms, and the string floats in the puddle. The large amount of water in the cup, however, quickly disperses the salt by dissolving it and then allowing it to spread throughout the entire cup. The freezing point is thus once again elevated, and the string is frozen into the ice cube. This all happens so quickly that the count of ten is sufficient to get the string frozen into the cube. If students continue to observe the cup, they will see that the ice cube gradually melts naturally, releasing the string. If they want to catch the string again, all they need to do is salt the cube again.

Expanding the idea:

What would happen if the ice cube was not in the cup of water when the salt was sprinkled on it? Can you design an experiment to prove that salt will make ice melt faster? Try it. If you live in a place that receives snow, have students find out what form of snow and ice removal is used. Do they spread salt? Are there other materials that are better than salt? Can you find out what they are?

How do you make ice cream? What is the purpose of the salt used? Why do you put salt in water before boiling eggs in it? Be careful on this one, it is NOT to raise the boiling point or to prevent the egg from cracking. Actually, it is to prevent the streamers of white from flowing freely all over the pot if you put a small hole in the shell before boiling it. Salt has the ability to cause these streamers to clog up this hole, thus preventing them from making a mess all over the pot.

For other cooking chemistry tidbits, an excellent source, although not at the reading level of any but the best students, is *The Cookbook Decoder, or Culinary Alchemy Explained* by Arthur E. Grosser, published in 1981 by Warner Books. This is an excellent resource book for all food-minded scientists, and junior scientists. It even makes good reading all by itself. Another book that is similarly concerned with science and food, although written at a much simpler level, is *Science Experiments You Can Eat* by Vicki Cobb, Lippincott, 1972.

Activity Sheet 5-7
Learning about water

Question: What happens when we "salt the water"?

Setting up the experiment:

Step 1) Look carefully at the sugar and salt that is being passed around the room. How are sugar and salt different from each other, how are they the same? Fill in the following chart, listing as many similarities and differences as you can.

SALT vs SUGAR

Similarities	Differences

Gathering the data:

Step 2) Start **PLAYING WITH SCIENCE: Temperature** and select DO AN EXPERIMENT from the Main Menu. Set the Set-Up options as follows:

Range:	MAX	35°C	(95°F)
	MIN	20°C	(70°F)
Type of display:	Line		
Time:	10 minutes		
Number of thermistors:	2		

Step 3) Select EXPERIMENT and press RETURN.

Step 4) Get two cups 3/4 full of room temperature water. Label one of the cups SUGAR and the other SALT. Put the white thermistor in the cup labeled SALT and the blue thermistor in the cup labeled SUGAR. Press RETURN to start collecting data.

Sunburst Communications © 1988

Step 5) Wait one minute while the temperature of the water stabilizes. This temperature is the starting temperature of the water.

Step 6) Stop taking data by pressing RETURN. Adjust the MAX and MIN temperatures by selecting *Graph* and typing in new values. The MAX should be about 2°C (4°F) above the original temperature of the water. The MIN should be about 2°C (4°F) below the original temperature of the water. Once these have been set you can exit the menu by pressing ESC.

Step 7) Record the time showing on the timer: _____

Highlight START and press RETURN to start taking temperatures again. Add two teaspoons of SALT to the cup labeled SALT, and stir with the thermistor. What is happening to the temperature of the water?

_____

When the temperature starts to go up, press RETURN to stop taking temperatures. Record the time showing on the timer: _____

Step 8) Press RETURN to start taking temperatures again. This time add two teaspoons of SUGAR to the cup labeled SUGAR and stir with the thermistor. Did the same thing happen? _____

_____

_____

Press RETURN to stop taking temperatures. Record the time showing on the timer: _____

Step 9) Switch to ANALYZE DATA before trying to answer the following questions. Unplug the thermistors and rinse them off in plain water before using the computer to work on the rest of this activity sheet.

Making observations:

Step 10) What is happening to the temperature of the water in the cups?

_____

_____

Does it stay the same in both cups? _____

_____

_____

In which cup is the temperature changing the most?

_____

_____

_____

Sunburst Communications © 1988

Thinking about the results:

Step 11) Switch to ANALYZE DATA and use the *Zoom* and *Print All* options to answer the following questions:

Temperatures of the cup with SALT in it (white thermistor)

Starting temperature _____
Lowest temperature after the salt was added _____
Ending temperature _____
Change in temperature _____

Temperatures of the cup with SUGAR in it (blue thermistor)

Starting temperature _____
Lowest temperature after the sugar was added _____
Ending temperature _____
Change in temperature _____

Which cup had the most dramatic temperature change, the one with the salt or the one with the sugar? _____

_____

How big was the temperature drop? _____

_____

Step 12) In this experiment, you observed what happened to the temperature of water when salt and sugar were dissolved. Is what happened a characteristic property of salt, of sugar, of water, or of the combination?

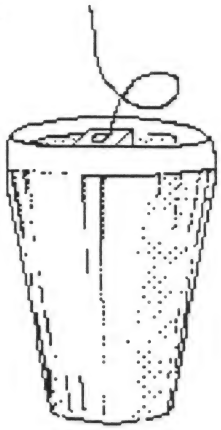
_____

_____

Sunburst Communications © 1988

Activity Sheet 5-7B
Learning about water

Question: Can you fish for ice in a glass?



Setting up the experiment and **Gathering the data:**

Step 1) Fill a glass with water and add an ice cube.

Step 2) Tie a loop, about half the size of the ice cube in a piece of string several inches long.

Step 3) Set the loop on top of the ice cube.

Step 4) Sprinkle some salt over the top of the cube where the loop sits. Count to ten.

Step 5) Gently lift the string. What happens to the ice cube?

Step 6) Put the ice cube back into the water and count to ten again. Lift. Did you get the cube this time too? Keep repeating this step until the ice freezes to the string. If you start again at Step 3 will you get the same results? Try it!

Sunburst Communications © 1988

Thinking about the results:

Step 7) Answer the following questions. If you are not sure what an answer should be, try to find it out by doing a quick experiment.

If you had left the string on the ice cube, without putting the salt on it, would it have stuck to the cube? _____

What did you put on the ice cube to make the string stick?

What happened to the surface of the ice when you put the salt on it?

What do you think happens to icy roads when salt is sprinkled on them?

Would sand have the same effect on the ice cube and string? Try it!

What do you think happens to icy roads when sand is sprinkled on them? _____

Sunburst Communications © 1988

Classroom Lesson Plan 6-1
Coffee cups and temperature

Question 6-1: What happens to a cup of coffee when it sits for several minutes?

Grade level: 4-7

Equipment needed:

- **PLAYING WITH SCIENCE: Temperature** with the white thermistor.
- One large coffee cup for each group in your class.
- A source of hot water. If you have very hot tap water nearby, that will work, but if your students are old enough to handle boiling water, use an electric kettle to produce sufficient quantities.
- Copies of Activity Sheet 6-1 for the entire class.

Concepts:

- Hot coffee/water cools if it is exposed to air.
- Graphs can be used to get a more detailed look at exactly how temperature changes as things cool down.

Objectives:

The students will be able to:

- State that hot coffee/water cools in a predictable manner.
- Sketch simple cooling curves.
- Use **PLAYING WITH SCIENCE: TEMPERATURE** to measure the temperatures of hot liquids and to analyze simple data.

General description of the experiment:

Coffee cups are filled with hot water and left to cool. The temperature is monitored throughout, and the program draws the cooling curve as a function of time. Students are asked to examine the results and to determine whether or not the temperature changes in a steady manner. To reinforce the idea of a cooling curve, students are asked to indicate when the greatest drop in temperature occurred and to relate this to the use of styrofoam cups in take-out food restaurants.

Classroom lesson:

1. This experiment is meant to give students practice in handling hot liquids and to prepare them for doing the explorations in Activities 6-2 and 6-3. Thus you should start the pre-experiment discussion with information on the proper handling of hot liquids.

2. Have your students describe how their parents react to someone getting burned in the home. You might want to conclude this discussion by describing first, second, and third degree burns, and how to handle the problems in each case. Information and attractive handouts on this subject are available from your local Red Cross chapter or fire department.

3. Start **PLAYING WITH SCIENCE: Temperature** and select DO AN EXPERIMENT from the Main Menu. Set the Set-Up options as follows:

Range:	MAX	90°C	(200°F)
	MIN	40°C	(100°F)
Type of display:	Line		
Time:	25 minutes		
Number of thermistors:	1		

   One-Computer Classroom: Use a large monitor to make the graphs visible to the entire class. Hand out a copy of Activity Sheet 6-1 to each student and let them answer the questions as the experiment proceeds. To do Step 7, either have the students fill in their charts following your suggestions, or use the *Print All* option to print out the graph and have the students use it to fill in their own charts.

   Multi-Computer Classroom: Each group should complete the experiment individually. Be sure that everyone starts with water as close to the same temperature as is possible. Using an electric kettle will make this task easier.

4. Before allowing students to collect data, remind them to think about what they expect to happen. They should start taking data and while that is going on, write down their answers to Questions 1 through 7 in the space provided on Activity Sheet 6-1.

5. If your class gets bored during the 25 minutes of data collection, you can have them move away from the computers for a class discussion, and then go back to the computers later to do the analysis.

6. After data collection is complete (the temperature of the water in the cup should have dropped by at least 25°C (40°F)), have the students switch to ANALYZE DATA. The cooling curve should be very easy to see, particularly if the water is very hot to start with.

7. Have students use the *See Data* option to fill in the charts on the second page of Activity 6-1.

8. Draw students' attention to the fact that most of the cooling takes place quite quickly, and then the rate of cooling slows down as the liquid comes closer to room temperature.

9. Now have students answer the questions on the third page of Activity Sheet 6-1. After they have written down their responses, discuss the answers with the class. Answers to Questions 6, 7, and 8 are particularly important since they form an introduction to the next experiments in this series.

10. With older students, record all of their results on the blackboard so that they can see that the experiment is independent of starting temperature, as long as it is fairly high.

11. Have students use the *Print All* option to print out copies of their graphs. Post these one over the other to demonstrate the overall uniformity of the shape of the cooling curve.

Getting the idea:

In your discussion, students may begin to wonder exactly why the graph has its distinctive shape. Since hot water radiates heat to the surrounding air, it will gradually cool off. If the volume of water is very small and the surface area quite large, the entire cup full of water will cool quickly at first since the difference between the temperature of the air and that of the water is very large. As the temperature continues to drop, the difference gets smaller and the rate at which cooling occurs slows down. Thus the shape of the graph gradually flattens out. When the water reaches room temperature, it will stop cooling completely, and the curve will become completely flat.

There are other factors that affect the rate of cooling and the shape of the curve. Hot water directly exposed to the cooler air will cool faster than the rest of the water in the cup. Stirring affects cooling since it brings the cooler surface water down, replacing it with hotter water that can now cool. The original temperature of the object is also important, as is the temperature of the surrounding air. Very hot objects radiate heat quickly, and show a greater temperature drop over time at the beginning. Objects in cooler surroundings will also lose heat more quickly.

If you have older students and have already discussed molecular motion with them, you can explain the appearance of the cooling curve by referring to the motion of the water molecules. As the faster moving molecules that make up hot water radiate heat, they lose energy and slow down (become cooler). Since they are now moving slower, they are less effective at radiating heat, and the rate of cooling slows.

If you are working with young students, the important concept is that cooling is a predictable behavior, and that we can study it to find out how to prevent cooling (if we want to keep our coffee warm). Studying cooling in detail is the topic of Activities 6-2 and 6-3.

Expanding the idea:

Discuss how coffee or tea is served at each student's home. How long do their parents usually wait after the coffee is served before they drink it? Contrast the use of styrofoam cups from a fast food restaurant with the coffee cups or mugs used at home. How do they differ? Do they cool off as quickly? Why don't we drink coffee out of a glass? Why do pottery coffee cups have handles on them, while most styrofoam cups do not? Can your students design an experiment to test their answers? Getting students to think about the variables involved is a first step in deciding how to control them and make meaningful decisions.

What will change if we leave the hot water to cool for more than 25 minutes? Have students set up the experiment again, but gather data for a long period, even up to 5 hours. How does the graph compare to the ones from the 25 minute time interval?

Activity Sheet 6-1
Coffee cups and temperature

Question: What happens to a cup of coffee when it sits for several minutes?

Setting up the experiment:

Step 1) Start **PLAYING WITH SCIENCE: Temperature** and select DO AN EXPERIMENT from the Main Menu. Set the Set-Up options as follows:

Range:	MAX	90°C	(200°F)
	MIN	40°C	(100°F)
Type of display:	Line		
Time:	25 minutes		
Number of thermistors:	1		

Step 2) Select EXPERIMENT and press RETURN. Fill a coffee cup full of very hot water. As quickly as possible, put the thermistor in the water and press RETURN to start recording data.

Step 3) While the program gathers and graphs the data, answer the following questions. If there are some you can't answer now, wait until after the data has been gathered and try again.

What do you think will happen?

1. Is the water warm, hot, or cold to the touch when you start measuring temperatures? _____

2. Will the water get hotter or colder as you wait? _____

3. Will the temperature change quickly or slowly? _____

4. What temperature do you think the water should be before you try to drink it?

   _____

   How long (in minutes) do you think it will take for the water to reach that temperature? _____

5 What temperature do you think water is when it is just warm to the touch?

   _____

   How long (in minutes) do you think it will take for the water to reach that temperature? _____

6. What temperature to feel cool? _____ How long? _____

7. What temperature to feel cold? _____ How long? _____

Sunburst Communications © 1988

Making observations:

Following the instructions above, record the temperature of the coffee cup over a 25 minute time interval. When the experiment has ended, switch to ANALYZE DATA. Use the *Pick Points By Time* and *See Data* options to fill in the following charts.

	Temperature __ °
starting temperature	
after 1 minute	
2 minutes	
5 minutes	
10 minutes	
15 minutes	
20 minutes	
25 minutes	

	Time measured in minutes	Change in Time
starting temperature ___ °	0 min.	
2° drop ➡ ___ °		
4° drop ➡ ___ °		
6° drop ➡ ___ °		
8° drop ➡ ___ °		
10° drop ➡ ___ °		

Sunburst Communications © 1988

Thinking about the results:

1. What happens to the temperature of the water as time passes? Where does the heat go? _____

2. What is the shape of the graph? Is it a straight line or a curve?

3. Does the temperature drop *steadily*, the same amount each time? (If the drop is steady, the change from line to line in the chart above will be the same every time.) _____

4. When does most of the cooling (the drop in temperature) occur, during the first few minutes or during the last few? _____

5. How long would you like to wait before you took a drink of the hot liquid?

6. List several things could you do to cool down the liquid faster (increase the rate of cooling). _____

7. List several things you could do to slow down the rate of cooling (keep the liquid warmer longer). _____

8. Suggest experiments to test your answers to Questions 6 and 7.

Sunburst Communications © 1988

Classroom Lesson Plan 6-2
Coffee cups and temperature

Question 6-2: What is the best material to use for a coffee cup?

Grade level: 4-7

Equipment needed:

- **PLAYING WITH SCIENCE:Temperature** with all three thermistors.
- Coffee cups or containers made of several different materials. Each group can investigate at most three different ones, but if you have several groups, the total number of different types can be much higher. Try to include cups made of styrofoam, china, pottery, glass, and metal, plus whatever else your students bring in.
- Sufficient hot water to fill all of each group's cups at the same time. An electric kettle works well.

Concepts:

- Different materials conduct heat quite differently.
- Graphs can be used to get a more detailed look at exactly how temperature changes as things cool.
- Ratings done on an objective scale, such as heat retention, can be used to determine the best object for a particular purpose.

Objectives:

The students will be able to:

- State some of the different characteristics that affect a coffee cup's ability to perform properly.
- Describe what happens to water as it sits in cups made of different materials.

General description of the experiment:

Each group of students gets three different types of coffee mugs, fills them with hot water, and lets them cool while monitoring their temperatures. By examining the resulting curves and doing some mathematical analysis on the actual measurements, students can see that the type of material does affect the ability of a mug to keep the coffee warm. Experiment 6-3 continues this investigation by asking the students to control more of the variables.

Classroom lesson:

1. Pre-experiment discussion should focus on identifying potential variations in the cups. Have students bring in coffee and tea cups from home or from fast food restaurants. Have your students suggest several different ways to sort them into groups. Use size, type of material, and shape for example. Discuss which cup is the best, and why the students feel that way. How could they prove that they were right? What are the most important things that a coffee or tea cup has to do? What do they all have in common? How are they different? Which of the differences is the most important?

2. Be sure students answer the **What do you think will happen?** questions on Activity Sheet 6-2. The point is to convince students of the necessity of actually doing an experiment to find out the answer, so emphasize that while they can hypothesize the results, they can't be sure until the experiment has been done.

3. Students need to be reminded that hot water is potentially dangerous, and that they need to be careful. If you haven't talked about burns and burn treatment, now is a excellent time to do so.

4. Remind students not to disturb the cups or thermistors while data is being taken. They must be particularly wary of stirring the water since that will affect the graphs unequally.

5. Start **PLAYING WITH SCIENCE: Temperature** and select DO AN EXPERIMENT from the Main Menu. Set the Set-Up options as follows:

Range:	MAX	90°C	(200°F)
	MIN	40°C	(100°F)
Type of display:	Line		
Time:	20 minutes		
Number of thermistors:	3		

   One-Computer Classroom: Do the entire experiment in front of the class on a large monitor. Hand out copies of Activity Sheet 6-2, and let students answer the questions as the experiment proceeds. Once the data has been gathered, move to ANALYZE DATA and use *Select Thermistors* and *Pick Points* to make it easy to fill in the chart. Either have each student fill in the chart following your suggestions, or use the *Print All* option to print the graph. In this case the students can use the printed graphs to fill in their own copies of the chart.

   Multi-Computer Classroom: Each group should complete the experiment individually. Be sure that every one starts with water as close to the same temperature as possible. Using an electric kettle will make this task easier.

6. Have students do the experiment. When they finish collecting data, they should switch to ANALYZE DATA. They can use the *Pick Points By Time* or *See Data* options to fill in the chart and answer the questions on Activity Sheet 6-2.

7. Discuss the results of the experiments with the whole class. Have the class decide what is most important about a cup to be used for hot coffee or tea. Everyone should agree that the type of material certainly makes a difference.

8. With older students, record sample data for each type of cup on the blackboard so that everyone can fill in the whole chart. Have them rate the materials from best to worst as part of the activity. For younger students, discuss the results, but do the rating for them. If groups have different types of cups, a run-off might be necessary to determine the best overall.

9. Questions 6, 7 and 8 require students to apply the knowledge gained in this experiment to a real life situation. Based on the results of the experiment, students should be able to eliminate some materials as unsuitable for coffee cups since they will allow the coffee to cool off too quickly or too slowly. Despite these results, these cups may still be used, and students should identify other reasons besides the ability to retain heat that would make someone want to use them.

Getting the idea:

While the data is being gathered, the students may notice that there seems to be very little variation in the temperatures of the coffee cups. The differences will be much more obvious when they use ANALYZE DATA to zoom in on specific sections of the graphs.

Just as was discussed in the last activity, water cools off by radiating heat to the surrounding air. The material between the hot water and the cooler room air controls the conduction of heat away from the water. Materials that are good heat conductors (like metal) cool off quickly because the heat is conducted rapidly away from the water through the material of the cup and into the air. This explains the heat felt on the outside of these kinds of cups.

Interestingly, both metal cups and pottery cups will get hot to the touch, but with different results. In the case of metal cups, heat loss is increased through this process by making it easier for the air near the surface of the cup to conduct the heat away. Pottery, on the other hand, actually retains its heat, and once it has been warmed up (explaining the initial quick drop in water temperature for this kind of cup), it is one of the best materials for maintaining the temperature of the water. In fact, unglazed pottery is a natural thermos material. It can also be used to keep drinks cold by wetting down the outside surface and letting evaporation (as discussed in Activity 5-1) naturally cool off the container and the liquid inside.

Expanding the idea:

What materials make the best coffee cups? Are all coffee cups made of these materials? Can you design an experiment to pick the best paper coffee cup?

Why do some coffee cups have handles, and others, like styrofoam ones, not? Can you design an experiment to decide why handles are put on some cups and not on others?

Does size make a difference? Did we control for size in this experiment? Can you design an experiment that would enable you to decide on the best size for a coffee cup?

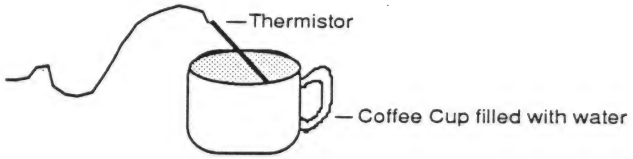
Does the thickness of the material that makes up the cup make a difference? Can you design an experiment to find out?

How does the starting temperature of the water affect the temperature changes? Does stirring the water while it cools affect the temperature measured? Can you design an experiment to test out your answer to these questions?

Do you know the characteristics of a great coffee cup yet?

Activity Sheet 6-2
Coffee cups and temperature

Question: What is the best material to use for a coffee cup?



Gathering the data:

Step 1) Start **PLAYING WITH SCIENCE: Temperature** and select DO AN EXPERIMENT from the Main Menu. Set the Set-Up options as follows:

Range:	MAX	90°C	(200°F)
	MIN	40°C	(100°F)
Type of display:	Line		
Time:	20 minutes		
Number of thermistors:	3		

Step 2) Select EXPERIMENT and press RETURN. Fill three different coffee cups 3/4 full of very hot water. As quickly as possible, put one thermistor in each cup and press RETURN to have the program start collecting data.

Step 3) While the program gathers and graphs the data, answer the following questions. If there are some you can't answer now, wait until after the data has been gathered and try again.

What do you think will happen?

1. Which of the cups is your personal favorite? _____
   Why? _____
   _____

2. Which of the cups do you think will be the best at holding in the heat?
   _____
   Why? _____
   _____

3. As the hot water (coffee) cools, where do you think the heat will go?
   _____
   _____

4. Sketch quickly what you think the graph will look like when this experiment is finished. How will it compare to the one drawn for Activity 6-1?

Sunburst Communications © 1988

Making observations:

5. After 20 minutes go to ANALYZE DATA and examine the resulting graph closely. Use *Pick Points* to select out the desired data points, and use *See Data* to fill in the following chart. Use *Print Screen* to print a copy of the graph to attach to this Activity Sheet, and label which line corresponds to which coffee cup.

Type of Coffee Cup	starting temp.	Temperature after:					total change in temp. (temp. at 20 min - starting temp.)
		1 min	2 min	5 min	10 min	20 min	
Styrofoam							
Heavy Pottery							
Glass							
Metal							
Light China							
Paper							

6. Which cup holds the coolest water after 1 minute? _____

   After 5 minutes? _____

   After 20 minutes? _____

7. Which cup holds the warmest water after 1 minute? _____

   After 5 minutes? _____

   After 20 minutes? _____

8. Feel the outside of each cup. Which is the warmest? _____

   Which is the coolest to the touch? _____

Sunburst Communications © 1988

Thinking about the results:

9. How did the outside of the cups get warm? Looking at the graphs and knowing which cup is the hottest on the outside, can you suggest an explanation of what might be happening? _____

10. Which material do you think makes the best coffee cups? Did doing this experiment help you decide? _____

11. If you ran a take-out restaurant where people go to get coffee and then leave before drinking it, which material would be the best to use for your coffee cups? _____

    Defend your decision based on the results of this experiment.

12. If you ran a fancy restaurant where people drank their coffee sitting at their table, which material would be the best to use? _____

    Again, defend your answer based on the results of this experiment.

13. Describe some other characteristics of coffee cups that might change your answers to Questions 11 and 12 above. _____

Sunburst Communications © 1988

Classroom Lesson Plan 6-3
Coffee cups and temperature

Question: How does the diameter of a coffee cup affect its ability to keep the coffee warm?

Grade level: 4-7

Equipment needed:

- **PLAYING WITH SCIENCE: Temperature** with all three thermistors.
- Coffee cups with several different diameters. Styrofoam cups are easily available in lots of variety, and will work very well, provided you put weights in them to make them more stable. Be sure to have at least one very small cup, one medium sized, and one large one. The more difference in size, the easier the results will be to interpret.
- You will need sufficient hot water to fill all of each group's cups at the same time. An electric kettle works well.
- Copies of Activity Sheet 6-3 for each member of the class.

Concepts:

- Air conducts heat away from hot water.
- The amount of surface exposed to the air determines the rate of cooling from this effect.
- Controlling variables means discovering what effects are important in terms of what measurement is desired.

Objectives:

The students will be able to:
- State that hot water is cooled by exposure to room temperature air.
- State that hot water cools faster in cups with larger diameters.
- Discuss what is meant by controlling variables.

General description of the experiment:

In both of the previous activities, the ability of coffee cups has been explored, but not much attention has been paid to controlling variables in a consistent manner. In this experiment, all the emphasis is on the control of one variable, the diameter of the coffee cup. By exploring only that one variable, students see a practical application of control of variables, and as well learn that a large diameter coffee cup loses heat relatively quickly when compared to a cup made of a similar material but with a smaller diameter mouth.

Classroom lesson:

1. Since this experiment is a follow up to Activities 6-1 and 6-2, students should be very familiar with the procedure. However, if you are working with young students, remind them again of the danger of hot water.

2. Discuss the importance of controlling variables. Depending on the time since the class did Activities 6-1 and 6-2, you may want to go over some of the variations in coffee cups, listing them in what the students think should be the order of importance.

3. Be sure the whole class realizes that size is an important variable. Have students suggest ways of controlling for size in an experiment similar to 6-2.

4. Hand out copies of Activity Sheet 6-3 to the entire class. Be sure everyone understands why this time we will be measuring the diameter of the cups.

5. Start **PLAYING WITH SCIENCE: Temperature** and select DO AN EXPERIMENT from the Main Menu. Set the Set-Up options as follows:

Range:	MAX	90°C	(200°F)
	MIN	40°C	(100°F)
Type of display:	Line		
Time:	20 minutes		
Number of thermistors:	1		

   One-Computer Classroom: Do the entire experiment in front of the classroom on a large monitor. Hand out copies of Activity Sheet 6-3, and let students answer the questions as the experiment proceeds. Once the data has been gathered, move to ANALYZE DATA and use *Select Thermistors* and *Pick Points* to make it easy to fill in the chart. Either have each student fill in the chart following your suggestions, or use the *Print All* option to print the graph, and have the students use the graph to fill in their own copies of the chart.

   Multi-Computer Classroom: Each group should complete the experiment individually. Be sure that every one starts with water as close to the same temperature as possible. Using an electric kettle will make this task easier. Have each group do the experiment. When they have finished collecting data, they should switch to ANALYZE DATA. They can use *Pick Points* or *See Data* to fill in the chart and answer the questions on Activity Sheet 6-3.

6. Discuss the results of the experiments with the whole class. Have the class decide which diameter is a better choice for a cup to be used for hot coffee or tea. Does diameter make as big a difference as material? Ask students to look at the results from Activity 6-2 before trying to answer this question.

7. With older students, record sample data for each size cup on the blackboard so that everyone can fill in the whole chart. Have them rate the sizes from best to worst as part of the activity. For younger students, discuss the results, but do the rating for them.

8. Questions 4 through 8 require students to apply the knowledge gained in this experiment to a real life situation. Based on the results of the experiment, most students should be able to make educated guesses as to the correct answers. Interested students should be encouraged to try and design experiments to test the validity of their hypothesized answers.

Getting the idea:

Discuss the results of the experiments by describing how the graphs show us the same information as the chart does. Ask students which they find easier to read.

Have the class decide what effect diameter has on the heat retention qualities of the cups. Spend time talking about controlling variables. This is the most important aspect of this experiment, and a difficult concept for people to understand.

As before, cooling occurs because the hot water radiates heat to the surrounding air, gradually cooling off. From Activity 6-2 we know that the material between the hot water and the cooler room air controls the conduction of heat away from the water. The more rapidly this occurs, the faster the cooling effect will be. Air is actually not a good conductor, and unless it is moving, is less important than the material making up the cups in the overall scheme of things. However, increasing the amount of surface exposed to the air will result in increased cooling eventually. The important thing is to control the variable.

For this experiment to work properly, the cups should only differ in diameter. If they are also made of slightly different materials, the experiment may very well fail. This is not a bad thing, since it will reinforce the importance of proper experimental design. Be sure to point out these problems if your students are mature enough to understand that many different things can affect the outcome of an experiment, not just the one or two aspects under study.

Expanding the idea:

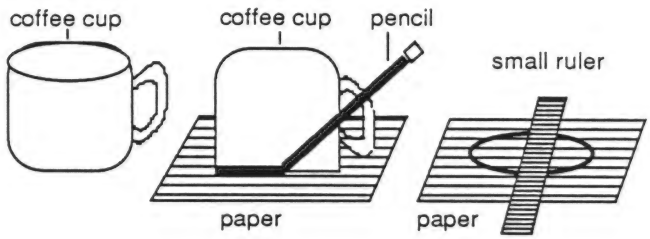
What size coffee cups are the best? Which is more important, the size of the cup (Activity 6-3) or the material that makes it up (Activity 6-2)? Which would your students rather use, a large pottery mug or a small one? What about a large glass cup or a small styrofoam one?

Give your students a list of different types of cups and have them line them up in order of ability to retain heat. Have them design and carry out an experiment to test their conclusions.

Question 8 opens an interesting field of inquiry, experiment design by experimental result. This is fundamental to the field of science, but may be a difficult concept for your students to understand.

Activity Sheet 6-3
Coffee cups and temperature

Question: How does the diameter of a coffee cup affect its ability to keep the coffee warm?



Gathering the data:

Step 1) Measure the diameters of the three coffee cups. Turn the cups over, trace around the top and then measure the diameters of these circles. Record the measurements on the chart below.

Step 2) Start **PLAYING WITH SCIENCE: Temperature** and select DO AN EXPERIMENT from the Main Menu. Set the Set-Up options as follows:

Range:	MAX	90°C	(200°F)
	MIN	40°C	(100°F)
Type of display:	Line		
Time:	20 minutes		
Number of thermistors:	1		

Step 3) Select EXPERIMENT. Get three different size cups, made of the same material. Fill each 3/4 full of very hot water. As quickly as possible, put the thermistors in each cup and press RETURN to start recording data.

Step 4) While the program gathers and graphs the data, answer the following questions. If there are some you can't answer now, wait until after the data gathering part of the experiment is finished and try again.

What do you think will happen?

1. Which cup do you think will be best at keeping the water warm?

   _____

   Why? _____

   _____

   _____

   _____

2. How are the three cups you are testing the same? _____

   _____

   _____

   _____

   _____

Sunburst Communications © 1988

3. How are the three cups you are testing different? _____

_____

_____

_____

_____

If they are only different in one way, that difference is the variable we are testing in our experiment. All of the other variables (the ways the cups are the same) are being controlled.

Making observations:

4. After 20 minutes go to ANALYZE DATA and examine the resulting graph closely. Use *Pick Points* to select out the desired data points, and use *See Data* to fill in the following chart. Print out a copy of the graph to attach to this Activity Sheet, and label which line corresponds to which diameter coffee cup.

Diameter of Coffee Cup	starting temp.	Temperature after:					total change in temp. (temp. at 20 min - starting temp.)
		1 min	2 min	5 min	10 min	20 min	

5. In which cup is the heat loss the greatest (the change in temperature the most?) _____

6. In which cup is the heat loss the least (the change in temperature the least?)

_____

7. Does the diameter of the cups make a difference? _____

If the answer is yes, which diameter do you think makes the best coffee cup?

_____

Did doing this experiment help you decide? _____

_____

_____

_____

_____

_____

Sunburst Communications © 1988

Thinking about the results:

8. If a cup had curved sides, or if the top was narrower than the bottom, would it make a difference? _____
   Why? _____
   _____
   _____

   Can you design an experiment to try and prove your answer?
   _____
   _____
   _____
   _____
   _____

9. Are all the cups made of exactly the same material? _____

   Are the thicknesses of the cups the same? _____

   Each of these questions concerns controlling variables. If the answer is yes to both questions, then we successfully *controlled these variables* in this experiment.

10. How many other variables can you list that might affect the ability of the coffee cups to hold in the heat? _____
    _____
    _____
    _____
    _____

11. How has the design of this experiment prevented the other variables from making too big a difference? _____

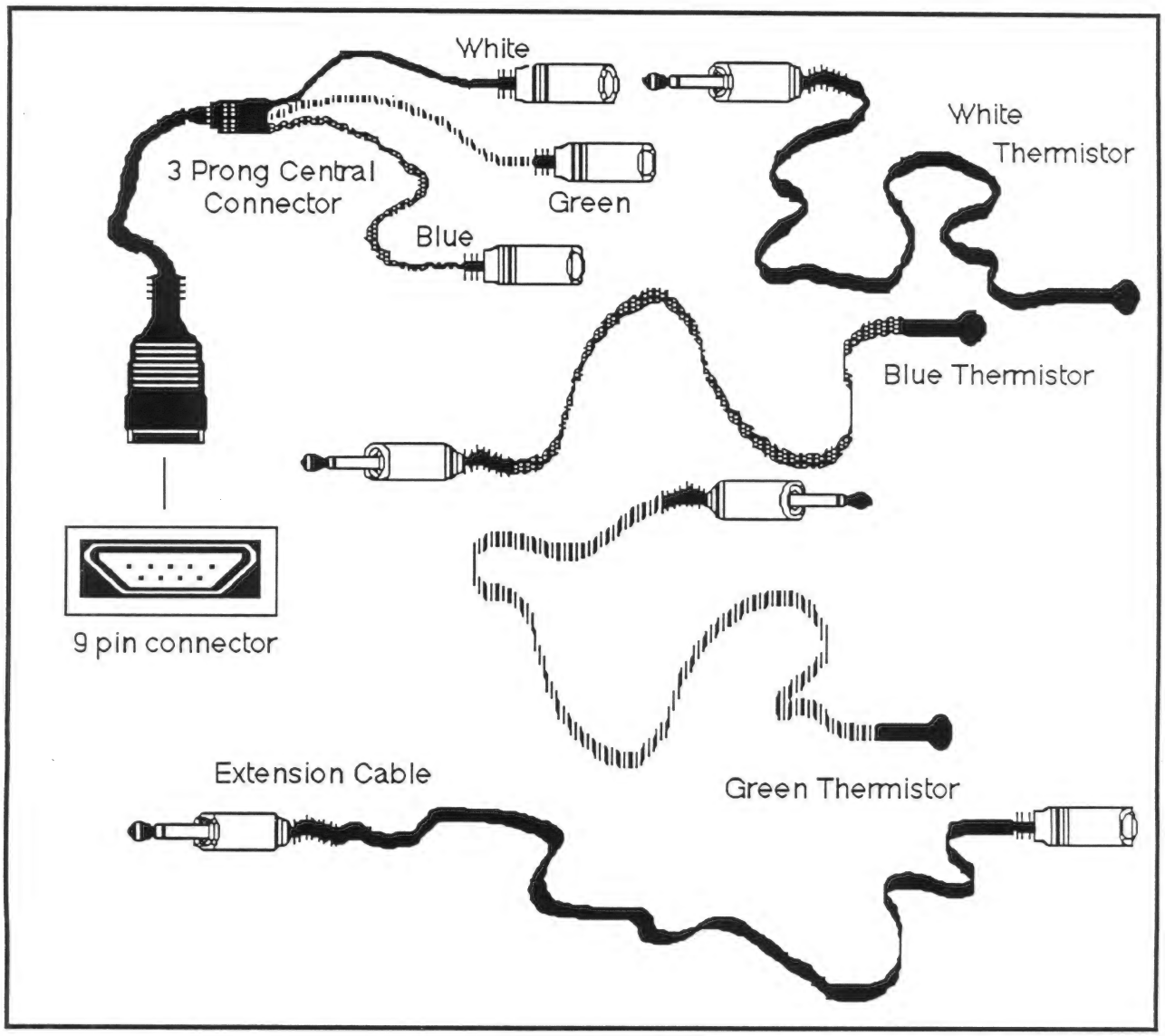
    Have we successfully controlled these variables? _____

    Can you think of a better design? _____
    _____
    _____
    _____
    _____

12. Controlling variables is very important. If the cups are not made of exactly the same material or exactly the same thickness, we can determine the importance of these variables by repeating Activity 6-2, using these cups instead of a random selection of cups. By doing this, we actually redesign an experiment based on the results of a different one.

Sunburst Communications © 1988

PLAYING WITH SCIENCE: Temperature
HARDWARE TECHNICAL GUIDE

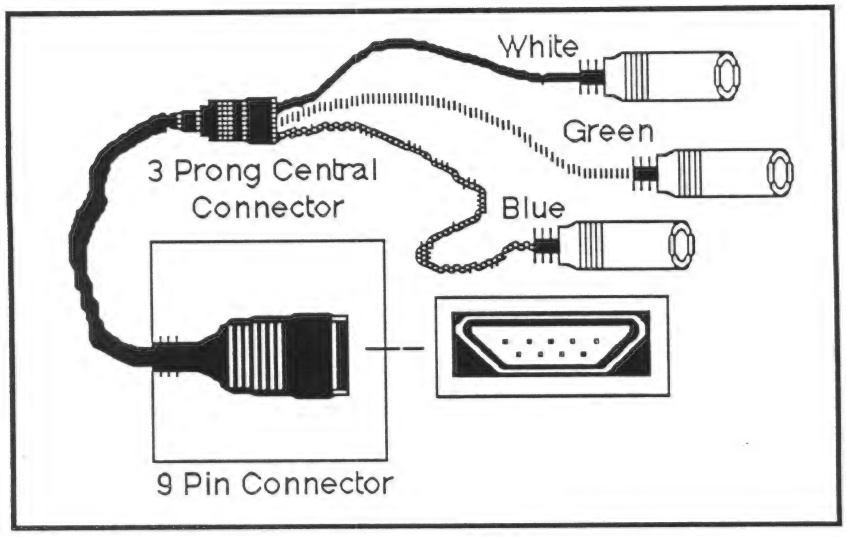


Description

The **PLAYING WITH SCIENCE: Temperature** hardware consists of five pieces:

1	3 Prong Central Connector
3	Color-coded Thermistor Probes (White, Blue and Green)
1	Extension Cable

3 Prong Central Connector



This cable, with its three color coded wires, provides the connection between the 'real world' and the computer. At one end are white, blue and green wires, color coded for the convenience of the students. The plugs at the ends of these wires are designed to receive the ends of the thermistor cables described below. At the other end is a 9-pin connector that will plug directly into the external game port of an Apple IIe/IIc/IIGS computer.

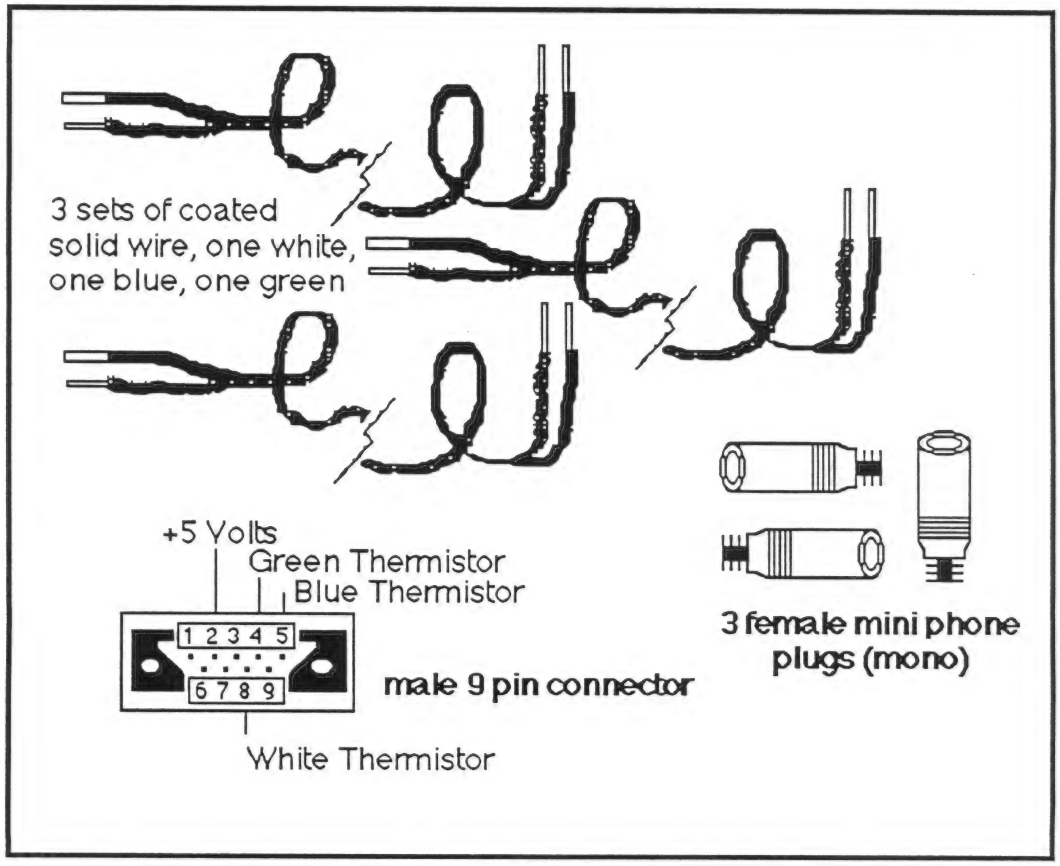
The Apple II+ does not have an external 9-pin game port, and you must obtain a 16 pin adaptor, available from Sunburst, in order to use the internal game port. One end of the adaptor fits on to the 9 pin connector, while the other end must be plugged into the internal game port. This port is in the form of a 16 pin socket, squeezed into the upper right corner of the main board of the computer (called the motherboard) under the lip of the computer's frame. One interesting note: while Apple IIc computers have only the external 9 pin connector, Apple IIe and IIGS computers actually have both connectors. Apple II+ computers have only the internal game port.

Note: If you are using an Apple IIc, only the white and blue thermistors will work. You must use an Apple II+, IIe, or IIGS if you want to do experiments that require the use of all three thermistors.

Make your own 3 prong central connector (9 pin version, for Apple IIe, IIc, and IIGS):

You will need:

- 1 male 9 pin connector.
- 3 16" sets of coated solid wire (Bell wire will do). Each set should contain two strands of wire. For best results, use color coded wire, one white set, one blue set, and one green set.
- 3 female mini phone plugs (mono).



Assemble the parts in the following order:

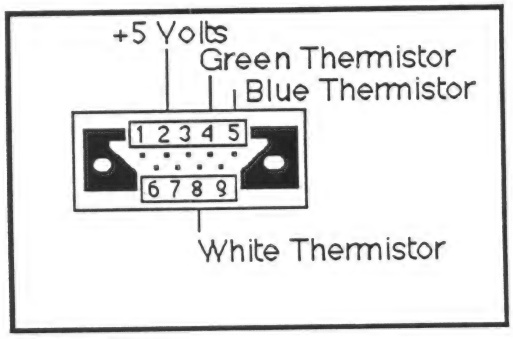
1. Remove the plastic coating from one end of each wire in the 3 sets of wires, leaving about 1/4" exposed (6 ends total).

2. Open one of the female mini phone plugs. You will see two small metal connectors. Thread two of the wires through the cover of the plug, pulling the ends free. Solder the end of one wire to one of the connectors, and the end of the other wire to the other connector. Screw the cover on tightly.

3. Repeat step 2 with the other two female plugs. You have just made three cables, one white, one blue, and one green.

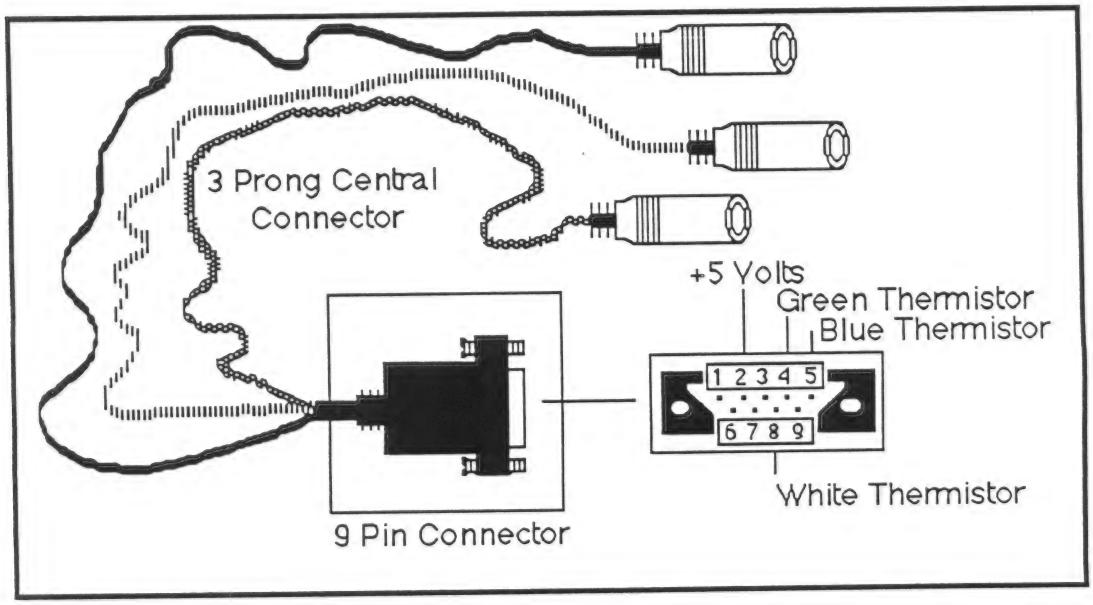
4. Remove the plastic coating from the other ends of each of the wires, leaving about 1/4" exposed on the ends (6 ends total again).

5. Carefully connect the wires to the proper pins on the 9 pin connector, according to the diagram below. One wire from each of the three cables (it doesn't matter which one) must be connected to the +5 volt pin on the 9 pin connector. This is pin #2. Carefully solder the wires in place.



6. Solder the other wire from the white cable to pin #8. Solder the wire from the blue cable to pin #5 and the wire from the green cable to pin #4.

7. Place the cover over the ends of the pins on the 9 pin connector. Seal the connector using a glue gun to help prevent the wires from coming loose.

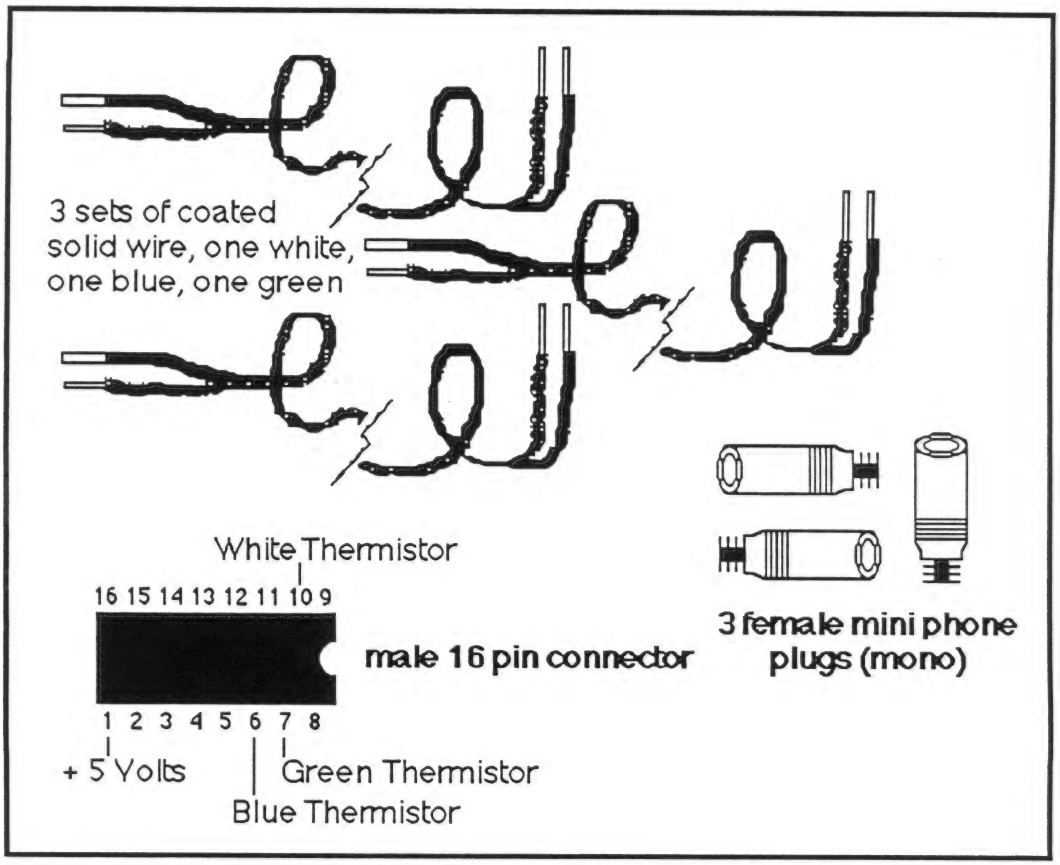


Your 3 prong central connector is ready to use!

Make your own 3 prong central connector (16 pin version, for Apple II+, IIe, and IIGS):

You will need:

- 1 male 16 pin connector.
- 3 16" sets of coated solid wire (Bell wire will do). Each set should contain two strands of wire. For best results, use color coded wire: one white set, one blue set, and one green set.
- 3 female mini phone plugs (mono).


3 sets of coated solid wire, one white, one blue, one green
White Thermistor
16 15 14 13 12 11 10 9
male 16 pin connector
3 female mini phone plugs (mono)
1 2 3 4 5 6 7 8
+ 5 Volts
Green Thermistor
Blue Thermistor

Assemble the parts in the following order:

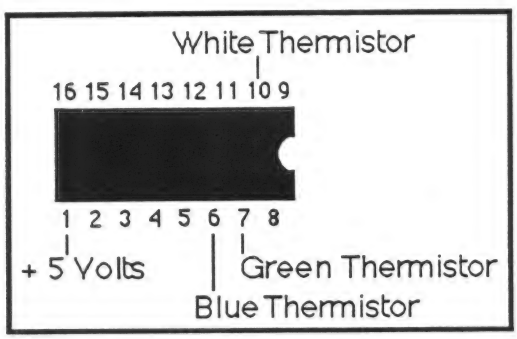
1. Remove the plastic coating from one end of each wire in the 3 sets of wires, leaving about 1/4" exposed (6 ends total).

2. Open one of the female mini phone plugs. You will see two small metal connectors. Thread two of the wires through the cover of the plug, pulling the ends free. Solder the end of one wire to one of the connectors, and the end of the other wire to the other connector. Screw the cover on tightly.

3. Repeat step 2 with the other two female plugs. You have just made three cables, one white, one blue, and one green.

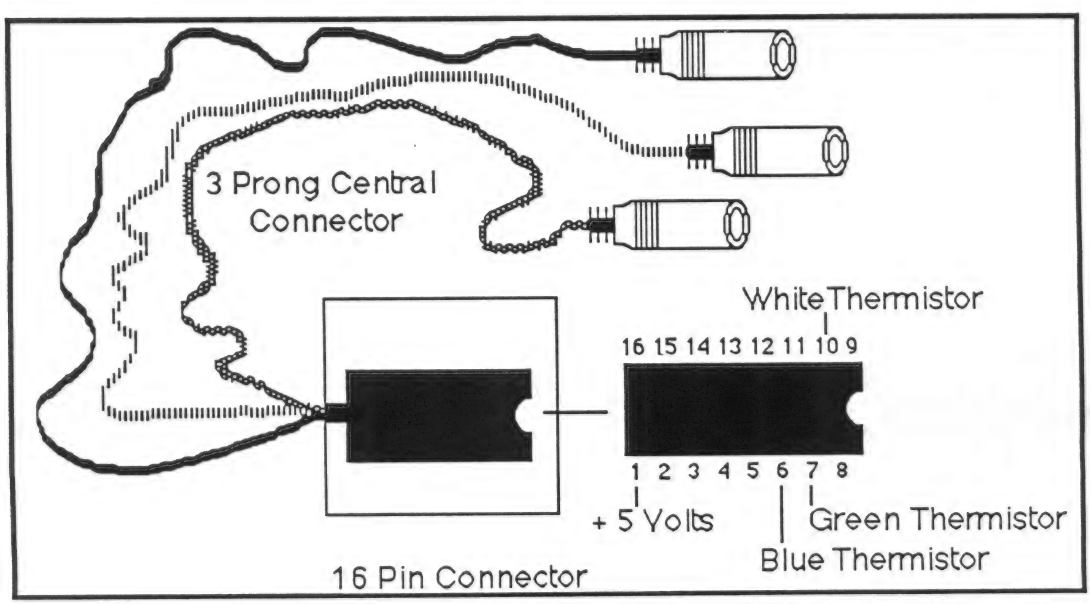
4. Remove the plastic coating from the other ends of each of the wires, leaving about 1/4" exposed on the ends (6 ends total again).

5. Carefully connect the wires to the proper pins on the 16 pin connector, according to the diagram below. One wire from each of the three cables (it doesn't matter which one) must be connected to the +5 volt pin on the 16 pin connector. This is pin #1. Carefully solder the wires in place.



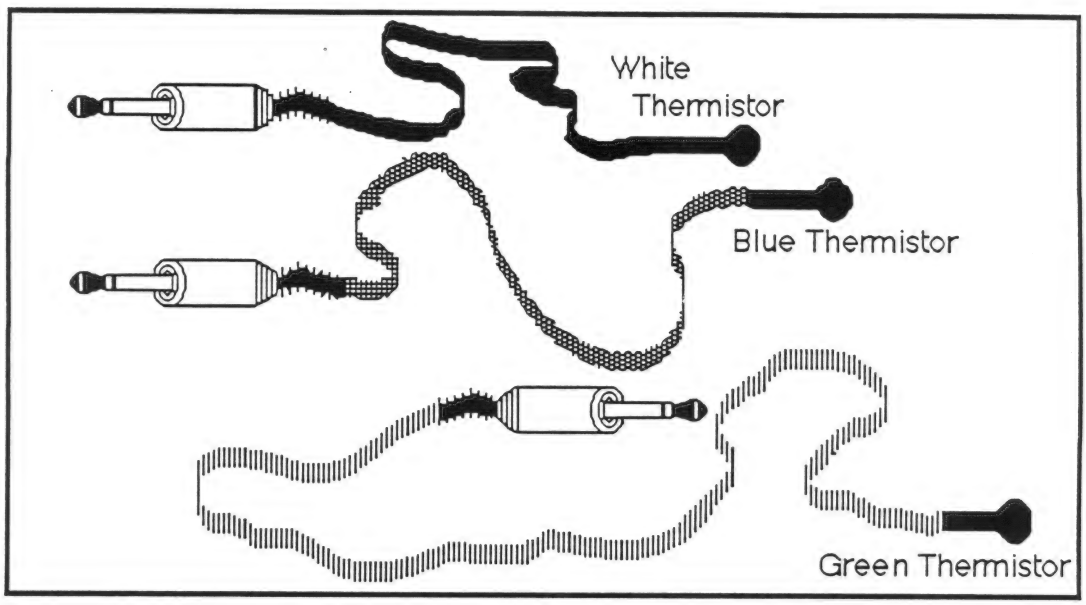
6. Solder the other wire from the white cable to pin #10. Solder the wire from the blue cable to pin #6 and the wire from the green cable to pin #7.

7. Place the cover over the ends of the pins on the 16 pin connector. Seal the connector using a glue gun to help prevent the wires from coming loose.


3 Prong Central Connector
White Thermistor
16 15 14 13 12 11 10 9
1 2 3 4 5 6 7 8
+ 5 Volts
Green Thermistor
Blue Thermistor
16 Pin Connector

Your 3 prong central connector is ready to use!

Thermistor Probes



The three thermistor probes provided have plugs on one end, and can be plugged directly into the 3 prong central connector. They are also color coded (white, blue, green) for ease of use. They consist of two wires, connecting a male mini phone plug (mono) to a 500K ohm thermistor in the tip.

The 500K ohm thermistor changes resistance as temperature changes, and it is this resistance change that the computer is monitoring. As the resistance changes, the computer calculates the equivalent temperature by a mathematical formula, and displays the information on the graph, thermometer, or as a digital readout.

Since any change in the resistance of the thermistor will be interpreted as a change in temperature, shorting out the plugs by connecting them together, or sticking a finger inside will result in false readings, and should never be attempted. Similarly, breaking the wires inside will result in a short circuit, resulting in artificially high temperatures. Mistreating the thermistors by chewing on the wires, bending them unduly, or letting water seep into the housing may also result in this occurring.

If abnormally high temperature readings are observed, it is very possible that the thermistors have been shorted out and must be replaced. This can be done by contacting Sunburst, or by making your own thermistors.

ACCURACY AND SENSITIVITY

The thermistor probes are very sensitive. This means that their resistance changes quickly when the temperature changes even a little bit. This change is reflected on the display by lines that are not exactly flat, but wiggle slightly as time passes. If this effect is annoying to your students, simply use a larger temperature range and the wiggle will effectively disappear.

When the temperature of the thermistor is changed radically, the resistance quickly changes until a value close to the actual measurement is reached. However, the thermistors will continue to change resistance, at a much slower rate, until the exact temperature is obtained. Generally, it takes about 15 seconds for the thermistor to stabilize close to the new temperature and another 15 seconds to get an exact reading. This explains the distinctive cooling and warming curves seen when the thermistors are subjected to rapid temperature changes. Having students count to 20 slowly before reading the temperature will give the thermistors time to stabilize.

Accuracy is a measure of both how well the program translates the resistance of the thermistor into a temperature reading, and how fine a scale can be used. Unfortunately, the sensitivity of the thermistors varies with temperature. At low temperatures, near the freezing point of water, a small change in temperature means a large change in resistance, and accuracy can actually be better than 0.01°. At high temperatures (near the boiling point of water), the situation is reversed, and larger changes in temperature are needed to affect the resistance. Actual accuracy may go down as far as 1°. The finest scale this program supports is 0.1°, a compromise between the two extremes. If you are working at very high temperatures, bear this limitation of the thermistors in mind, and be sure that the students understand that mechanical devices also have limitations.

CALIBRATION

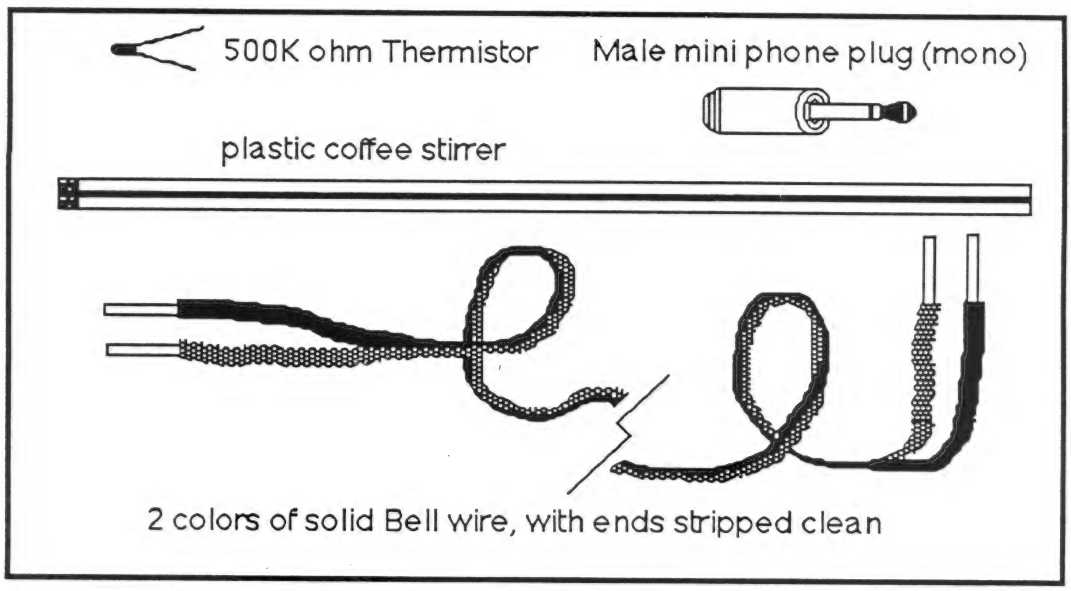
The thermistors were chosen to offer a compromise between durability, accuracy, and sensitivity. There will be a variation from one to another as they come out of the package, and even when they are used with different computers. If you want to be sure that all three thermistors read the same temperature at the same time, you must first use the *Calibration Utility* in the UTILITIES section of the program. There are instructions on page 49 of this guide.

Even if calibration is done correctly, there will still be variation in readings from thermistor to thermistor because they are only accurate to within 5%. That means a possible variation of 2° when the thermistors are reading 100°C, and a variation of 0.05° when they are measuring 0°C. If you plan to use this program to measure a critical temperature, be prepared to explain why measurements that should be the same are actually slightly different.

Make your own thermistor probes:

You will need:

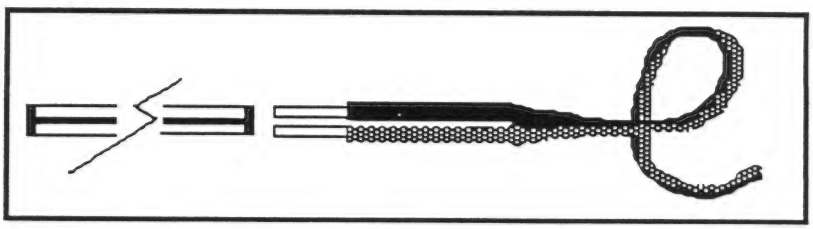
- a 500K ohm thermistor (this part may be difficult to find, but it should be possible to special order it from a good electronic supply house)
- 2 pieces (each 3 feet long) of coated solid wire (Bell wire will do)
- a standard male mini phone plug (mono)
- a plastic coffee stirrer


500K ohm Thermistor
Male mini phone plug (mono)
plastic coffee stirrer
2 colors of solid Bell wire, with ends stripped clean

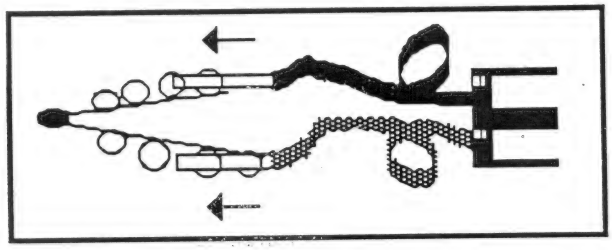
Assemble the parts in the following order:

1. Remove the plastic coating from the ends of the wires, leaving about 1/4 " exposed.

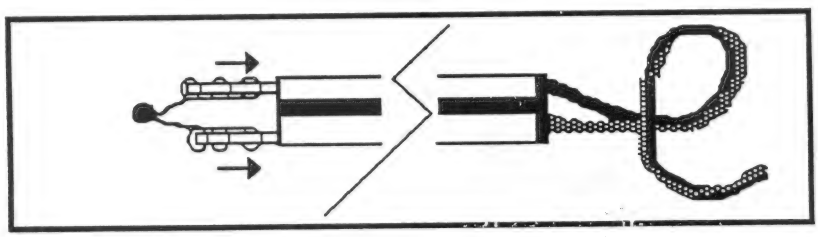
2. Thread the wires through the holes in the plastic coffee stirrer. Pull them well clear of the plastic.



3. Make a solid, but smooth connection between the ends of the thermistor leads and the pieces of wire. Solder them in place.



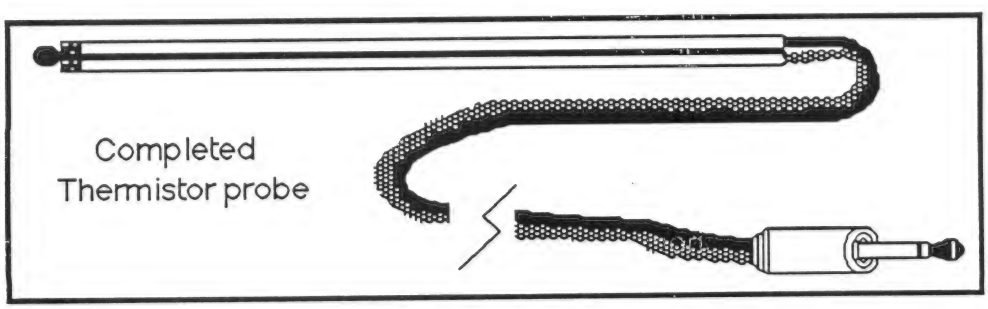
4. Carefully pull the wires, and the ends of the thermistor back into the coffee stirrer. Be sure that as much of the wire is inside the stirrer as is possible.



5. Coat the end of the thermistor/plastic stirrer ensemble with quick drying epoxy. When this drys, it will form a reasonably waterproof cover. Note that if the seal is not completely waterproof, the thermistor may short and give abnormally high readings. If this occurs, wait until the thermistor wires dry, and recoat with epoxy.

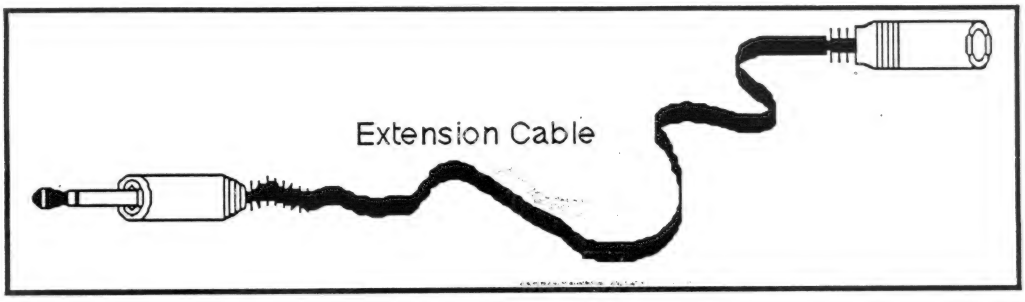
6. Open the plug housing and connect one wire to one side of the male mini phone plug, the other end to the other side. Close the plug housing.

7. Use the *Calibration Utility* in the UTILITIES to calibrate your new probe.



Your thermistor probe is ready to use!

Extension Cable



This 2 1/2 meter long (about 10') cable is designed to extend the reach of any one of the three thermistors. Simply plug it in the appropriate plug in the 3 Prong Central Connector and then plug the thermistor into the other end. Since the resistance of the thermistors is so high (500K ohm), the small amount of additional resistance introduced by the longer cable will not affect your results.

Make your own extension cable:

You will need:

- one male mini phone plug (mono).
- one female mini phone plug (mono).
- 2 pieces (each 10 feet long) of coated solid Bell wire.

Assemble the parts in the following order:

1. Remove the plastic coating from one end of each of the wires, leaving about 1/4" exposed on both ends.

2. Open the male mini phone plug. You will see two small metal connectors. Thread the wires through the cover of the plug, pulling the ends free. Solder the end of one wire to one of the connectors, and the end of the other wire to the other connector. Screw the cover on tightly.

3. Remove the plastic coating from the other ends of each of the wires, leaving about 1/4" exposed on both ends.

4. Open the female mini phone plug. You will see two small metal connectors just like those on the male plug. Thread the free ends of the wires through the cover of the plug, pulling the ends free. Solder the end of one wire to one of the connectors, and the end of the other wire to the other connector. Screw the cover on tightly.

Your extension cable is ready to use!

Bibliography

Diamond, Susan (editor); *Discovering Science: Projects For Everyone*; Sunburst Communications, Pleasantville, N.Y.; 1986

This is not a book, but a notebook with 26 open-ended experiments and project ideas. Controlling variables and discovery learning through structured play are the primary emphasis of the activities described in this publication. The Solar Collector activity in particular is both interesting and relevant to temperature experiments.

Drotar, David; *Fun Science, A Learn And Discover Book*; Playmore Inc., and Waldman Publishing Corp.; New York, New York; 1986

This book is one of a set of inexpensive paperback books designed for the home, but with excellent classroom applications. Almost 250 different science experiments are described, all chosen for dramatic impact and designed to develop student curiosity. While not all are appropriate for use in the classroom, many can be adapted to that use, or used as science projects or idea starters. These are great just as a source of quick demonstrations to introduce the science portion of a lesson plan.

Ontario Science Centre; *Scienceworks*; Kids Can Press, Toronto, Ontario, Canada, 1984

Not specifically for teachers, this is a book of 65 simple and fast science experiments and demonstrations that can be performed using materials readily available. Since each activity is carefully written to fit on a single page, this book is perhaps best used as a source for handouts, for individual projects, or for at home experiments to be discussed in class.

Saul, Wendy with Newman, Alan; *Science Fare: An Illustrated Guide & Catalog of Toys, Books & Activities for Kids*; Harper & Row, New York, New York, 1986

This paperback book is an exhaustive listing of books on different science subjects, including short descriptions of many of the titles recommended. This book is worth getting just for the detailed list of catalogs. In addition to supplying the names and addresses (and phone numbers) of such standard sources as Radio Shack, Edmund Scientific, and Carolina Biological Supply, it also gives addresses for several museum stores that offer mail order services, and will send catalogs on request. There is also a section that suggests ways of getting more science into the schools.

Sund, Robert; Tillery, Bill; and Trowbridge, Leslie; *Investigate And Discover, Elementary Science Lessons*, Allyn and Bacon, Inc., Boston, Mass., 1975

Old, and probably only available in education libraries, this book is a bible filled with detailed instructions, including concepts and behavioral objectives for each activity. 200 different experiments, in a variety of science areas, all including grade level and simple diagrams.

Working with Your Computer: Apple II+, IIe, IIc

Installing the hardware

1. Connect the three prong connector cable to the game port on the back of the computer.
2. Attach the thermistor probes to their appropriate plugs on the connector cable. The probes and plugs are color coded for convenient matching.
3. For more detailed information about installing the hardware, see pages 4-7.

Note: If you are using an Apple IIc, only the white and blue thermistors will work. You must use an Apple II+, IIe, or IIGS if you want to do experiments that require the use of all three thermistors.

Using the program

1. Turn on the television or monitor.
2. Insert the disk into the disk drive with the label facing up and on the right.
3. Close the door to the disk drive.
4. Turn on the Apple II. (The switch is on the back left side of the computer.)
5. You will see a red light on the disk drive turn on. If the disk drive light does not turn off in about 10 seconds, turn the Apple off and make sure your disk is placed correctly in the disk drive.
6. The Sunburst logo will appear on the screen, followed by the opening screen of the program.
7. Follow directions given in the program.
8. If you wish to stop during the program, hold down the CONTROL key and press the E key.

Turning off the system

1. Remove the disk from the drive and put it in a safe place.
2. Turn off the computer.
3. Turn off the television or monitor.

Working With Your Computer: Apple IIGS

To allow your Apple IIGS to work properly with Sunburst software, certain Control Panel settings have been suggested. The Apple IIGS retains these settings even after the power is turned off.

To use the Control Panel

- Turn on the Apple IIGS and monitor.
- Enter the Control Panel main menu by holding down the CONTROL and OPTION keys, and then press RESET (the rectangular key located above the number keys). If your Apple IIGS is in an Apple //e case, use the ♦ key instead of OPTION.
- Press the 1 key to enter the Control Panel.
- Use ↓ and ↑ to highlight the feature you want to change and press RETURN. Again use ↓ and ↑ to highlight a specific option and change it by using the ← and → keys.
- After you have finished making changes, select Quit to use the Apple IIGS.

To change the display

- Highlight **Display** and press RETURN.
- Set **Type** to **Color.**
- Set **Columns** to **40.**
- Set **Text** to **White.**
- Set **Background** to **Black.**
- Set **Border** to **Black.**
- Press RETURN to save the changes and to go back to the Control Panel.

To change the system speed

- Highlight **System Speed** and press RETURN.
- Set **System Speed** to **Normal.**
- Press RETURN to go back to the Control Panel.

To change the slots

- Highlight **Slots** and press RETURN.
- Set **Slot 1** to **Printer Port.** If you are using a printer card, select the slot number your printer card is in.
- Set **Slot 6** to **Disk Port,** if you use a 5.25-inch drive connected to the disk drive port.
- Set **Slot 6** to **Your Card,** if you use a 5.25-inch drive connected to a controller card in Slot 6.
- Set **Startup Slot** to **Scan.**
- Press RETURN to go back to the Control Panel.

What Happens If...? – Sunburst Courseware and Warranty

1. What happens if a program will not load or run?

   Call us on our toll-free number and we will send you a new disk.

2. What if I find an error in the program?

   We have thoroughly tested the programs that Sunburst carries so we hope this does not happen. But if you find an error, please note what you did before the error occurred. If an error message appears on the screen, please write the message down. Then fill out the evaluation form or call us with the information. We will correct the error and send you a new disk.

3. What happens if the courseware is accidentally destroyed?

   Sunburst has a lifetime guarantee on its courseware. Send us the product that was damaged and we will send you a new one.

4. How do I stop the program in the middle to go on to something new?

   These programs can be ended at any time by holding the CONTROL (CTRL) key and pressing the E key. To change disks, select the End option on the menu and insert a new disk.

5. Can I copy this disk?

   The material on the disk or cassette is copyrighted. You *should not* copy the courseware.

6. Can I remove the disk from the disk drive after I have loaded the program?

   No, the program requires the disk to be in the disk drive at all times. For other permissions and restrictions, see the permissions sheet at the front of this guide.

SUNBURST

39 Washington Ave. • Pleasantville, NY 10570-2898
USA: (800) 431-1934 • Canada: (800) 247-6756
Or call collect (914) 769-5030

SUNBURST
COMMUNICATIONS

TEACHER EVALUATION FORM

Please indicate your reactions to the following questions about this Sunburst program. Use the space at the bottom of the page to summarize your overall feelings about the program. The other side of this evaluation may be reproduced and used for student evaluations.

NAME OF SUNBURST PROGRAM

COMPUTER SYSTEM / MODEL

NAME OF SCHOOL

GRADE LEVEL OF SCHOOL

ADDRESS

YOUR NAME

CITY STATE ZIP

TITLE

DATE

PHONE NUMBER

1. Does the material *meet its objectives* as stated in the teacher's guide?

2. What suggestions would you make for improvement in the teacher's guide?

3. Is this program educationally valuable to you? Why?

4. With which grade level would you use the program?

5. Will this program interest your students enough that they will want to use it more than once?

6. How would you use this program with your students?

Please use this space to describe your overall reaction to the program.

Did you order this product for <u>evaluation</u> or as a <u>purchase</u>? (Circle one.)

STUDENT EVALUATION FORM

1. What is the name of the program that you used? _____

_____

2. Would you like to use this program again? Explain why.

_____

_____

3. Did you understand the instructions?

_____

_____

4. Were the pictures in the program interesting?

_____

_____

5. What did you learn from the program that you didn't know before?

_____

_____

6. What <u>didn't</u> you like about the program?

_____

_____

Fold into thirds, tape closed (do not staple) and mail.

SUNBURST COMMUNICATIONS

NO POSTAGE NECESSARY IF MAILED IN THE UNITED STATES

BUSINESS REPLY MAIL
FIRST CLASS PERMIT NO.53 PLEASANTVILLE, NY

POSTAGE WILL BE PAID BY ADDRESSEE

Sunburst Communications
39 Washington Avenue
Pleasantville, NY 10570-9971

THERMOFIT® RNF-100
AWM 3173 C

THERMOFIT® RNF-100 125°C RA
THERMOFIT® RNF-100 125°C RA
THERMOFIT® RNF-100 125°C RA